REPORT

ON THE

COLLECTION AND TREATMENT

OF THE

SEWAGE

OF THE

CITY OF PHILADELPHIA

1914

Compliments of

George S. Webster, Chief Engineer,
Bureau of Surveys,
Philadelphia, Pa.

REPORT

ON THE

COLLECTION AND TREATMENT

OF THE

SEWAGE

OF THE

CITY OF PHILADELPHIA

1914

TO PROTECT THE PUBLIC HEALTH

BY MAINTAINING THE RIVERS AS FIT SOURCES OF WATER SUPPLY

TO PROVIDE FOR THE COMFORT OF THE CITIZENS

BY RESTORING THE SEWAGE LADEN STREAMS TO A CLEAN CONDITION

TO IMPROVE THE PORT

BY PROVIDING A CLEAN, SANITARY HARBOR

THE CITY OF PHILADELPHIA

SHOULD EXPEND \$5,000,000 ANNUALLY FOR THE NEXT FIVE YEARS FOR THE CONSTRUCTION OF THE NECESSARY WORKS FOR THE

COLLECTION, TREATMENT AND DISPOSAL OF SEWAGE

Phil

REPORT OF THE DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
1914

GEORGE S. WEBSTER
Chief Engineer
GEORGE E. DATESMAN
Principal Assistant Engineer
W. L. STEVENSON
Assistant Engineer

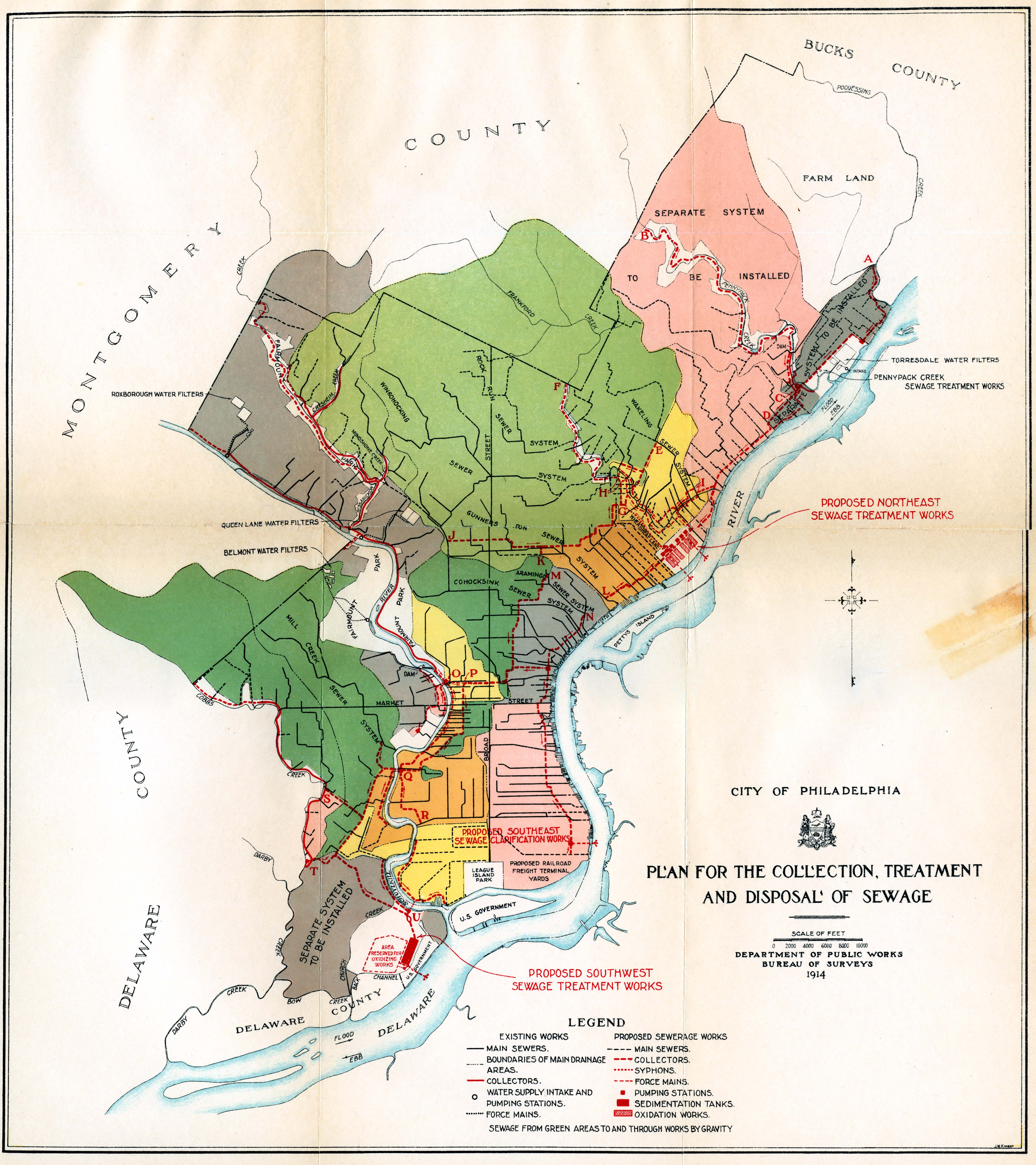
SCOPE OF REPORT.

A report of the Department of Public Works, Bureau of Surveys, City of Philadelphia, recommending a comprehensive plan for the collection, treatment and disposal of the sewage of the city, prepared in pursuance of an Ordinance of Councils approved July 20, 1907.

PART I consists of a concise summary of the report with recommendations.

PART II briefly explains the water supply, sewer system, and water courses of Philadelphia; states the problem of sewage disposal and discusses the policies adopted for its solution; describes the works to be constructed; recommends the order of procedure to be followed and gives estimates of the cost of construction, operation and maintenance of the works.

PART III consists of appendices in which the more important parts of the report are dealt with in detail, including the Ordinance of Councils and Act of Assembly under which the investigations have been made; and topography, sewer system, population studies, sewer gaugings, and sanitary surveys of the water courses; description of works already constructed by the city as parts of the plan; and report of examination of sewage disposal works in European cities.


CITY OF PHILADELPHIA
PLAN FOR THE COLLECTION, TREATMENT AND DISPOSAL OF SEWAGE
SCALE OF FEET
0 2000 4000 6000 8000 10000
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
1914
BUCKS COUNTY
MONTGOMERY COUNTY
DELAWARE COUNTY
FARM LAND
SEPARATE SYSTEM TO BE INSTALLED
TORRESDALE WATER FILTERS
PENNYPACK CREEK SEWAGE TREATMENT WORKS
PROPOSED NORTHEAST SEWAGE TREATMENT WORKS
ROXBOROUGH WATER FILTERS
QUEEN LANE WATER FILTERS
BELMONT WATER FILTERS
WINGOHOCKING SEWER SYSTEM
ROCK RUN SEWER SYSTEM
GUNNERS RUN SEWER SYSTEM
WAKELING SEWER SYSTEM
COHOCKSINK SEWER SYSTEM
ARAMINGO SEWER SYSTEM
MILL CREEK SEWER SYSTEM
FAIRMOUNT PARK
MARKET STREET
BROAD STREET
PETTYS ISLAND
PROPOSED SOUTHEAST SEWAGE CLARIFICATION WORKS
LEAGUE ISLAND PARK
PROPOSED RAILROAD FREIGHT TERMINAL YARDS
U.S. GOVERNMENT
AREA RESERVED FOR OXIDIZING WORKS
PROPOSED SOUTHWEST SEWAGE TREATMENT WORKS
SEPARATE SYSTEM TO BE INSTALLED
DELAWARE RIVER
FLOOD
EBB
LEGEND
EXISTING WORKS
MAIN SEWERS.
BOUNDARIES OF MAIN DRAINAGE AREAS.
COLLECTORS.
WATER SUPPLY INTAKE AND PUMPING STATIONS.
FORCE MAINS.
PROPOSED SEWERAGE WORKS
MAIN SEWERS.
COLLECTORS.
SYPHONS.
FORCE MAINS.
PUMPING STATIONS.
SEDIMENTATION TANKS.
OXIDATION WORKS.
SEWAGE FROM GREEN AREAS TO AND THROUGH WORKS BY GRAVITY

PART I

SUMMARY OF CONDITIONS, CONCLUSIONS AND RECOMMENDATIONS

CONDITIONS

Population

1910,	1,549,008	Census
1914,	1,657,810	Estimated
1950,	3,095,000	Estimated.

The Water Supply

The City of Philadelphia obtains a wholesome water supply by the purification of water taken from the Delaware River near the northern (or upstream) limit of the city and from the Schuylkill River above Fairmount Dam.

The Sewer System

The sewage of Philadelphia is now being discharged into the water courses from a combined system of sewers, except on the watershed of the Schuylkill River above Fairmount Dam, where the separate system is installed.

The Water Courses

The Schuylkill River above Fairmount Dam, and the Wissahickon Creek and its tributaries, are protected from sewage pollution from Philadelphia by intercepting sewers discharging below Fairmount Dam.

The sewage and first flush of rain-water from sewers tributary to Pennypack Creek are collected and completely treated before discharge into the creek.

A collecting sewer for sewage and first flush of rain-

water is nearly completed along the Philadelphia side of Cobbs Creek. Its present polluted condition is largely due to the sewage discharged from the adjoining county.

Frankford Creek and the Schuylkill River below Fairmount Dam are seriously polluted by the discharge into them of crude sewage.

The Delaware River is now receiving all the sewage of Philadelphia, either directly from the sewers or indirectly from Frankford Creek, Cobbs Creek and the Schuylkill River, in addition to that from other communities on the watershed.

During the summer the oxidizing power of the river water is so severely taxed that delay in the construction of works for the collection and treatment of the sewage will result in the creation of nuisance in the river channel and the public health will be endangered by overtaxing the economical and safe operation of the Torresdale water filters.

The Problem

The problem of sewage disposal confronting the City of Philadelphia is four-fold:

1. To collect and treat the sewage so as to protect the public health and to prevent undue pollution of the water taken from the Delaware River at the Torresdale water filters.

2. To promote the comfort and prosperity of the people by abating the nuisance now existing due to sewage pollution of Frankford and Cobbs Creeks, the lower Schuylkill River and the docks of the Delaware River.

3. To enhance the development of the port and create attractive conditions by restoring and maintaining the rivers and streams in a clean condition.

4. To accomplish these results promptly and progressively with the most economical expenditure of funds.

CONCLUSIONS

Collection

The sewage which is gathered by the various sewer systems of the City should be intercepted and conveyed by transverse collecting sewers to three sites, as follows:

A treatment works on the Delaware River south of Bridesburg for the northern part of the city.

A clarification works on the Delaware River in the vicinity of Greenwich Point for the southeast part of the city.

A treatment works in the southern part of West Philadelphia, near the mouth of the Schuylkill River, for the central and western parts of the city.

Treatment

The first method of sewage treatment at the northeast and southwest works should be coarse screens, grit chambers and two-story sedimentation tanks of the Emscher type. As the volume of river water available for assimilation of the effluent of the works remains practically the same, while the amount of sewage produced by the City steadily increases, due to growth in population, it may be necessary in the future to compensate for this increase in amount of sewage by more refined treatment, which will probably consist in the oxidation of the tank effluent in percolating filters or by such other methods as may be approved at that time.

The treatment of the sewage carried to the southeast works should consist of coarse screens, grit chambers and fine screens.

Disposal

The effluents of these works should be disposed of by diffusion in the water of the Delaware River through submerged outfalls, so located in the bed of the river that the effluent will be rapidly distributed in the great tidal flow and so utilize to the fullest extent the oxidizing power of the river.

RECOMMENDATIONS

It is recommended that $5,000,000 be appropriated at once for the purchase of land at the sites of the three proposed treatment works; for the construction of the collecting sewers to intercept sewage tributary to Frankford and Pennypack Creeks and to the Delaware River between the treatment works to be located near Bridesburg and the mouth of Poquessing Creek; and for the construction of sewage treatment works at the northeast site. These works will protect the Delaware River in the vicinity of the source of the water supply and maintain the two creeks in a clean condition.

It is recommended that subsequent appropriations be made as rapidly as possible for the construction of the collecting sewers, pumping stations, treatment works and appurtenances, generally in the order and for the works designated.

$5,700,000 for collecting sewer and treatment works for the sewage from the populous districts of West Philadelphia, so as to in part abate the present pollution of the Schuylkill River.

$4,800,000 for collecting sewers, pumping stations, extensions to the treatment works and appurtenances for practically all sewage tributary to the Schuylkill River from the city.

These works will restore and maintain the Schuylkill River in a clean condition.

$3,400,000 for collecting sewers which will intercept and convey to treatment works without pumping a part of the sewage tributary to the Delaware River between the works to be located near Bridesburg and Market Street, and for extensions to the treatment works.

$3,500,000 for low level collecting sewers along the Delaware River front from the treatment works, to be located near Bridesburg, to Greenwich Point, with pumping stations and appurtenances; the construction of the southeast clarification works; and enlargements of the existing treatment works.

These appropriations for construction, aggregating $22,400,000, will complete the system of collectors and provide for the treatment of all the dry weather flow of sewage and the first flush of rainfall. It is estimated that the operation and maintenance of these works will require annual appropriations of $500,000, in addition to which appropriations of at least $2,000,000 should be made each year for the construction of main and branch sewers to keep pace with the growth of the city.

The collecting sewers recommended are of capacity ample for the year 1950, but before that time it will be requisite that the treatment of the sewage be carried to a greater degree of refinement. It is estimated that the extensions to the works to meet the conditions of the year 1950 will cost $12,200,000 and will make a total cost of the completed system at that time of $34,600,000.

It is also recommended that co-operation be had between the States of Pennsylvania and New Jersey, so as to secure concordant action for the treatment of the sewage of communities in these states which is discharged into the Delaware River or its tributaries.

PART II

INTRODUCTION

The Bureau of Surveys is charged with the responsibility of planning, designing and constructing the sewer system of Philadelphia. For many years its officials have realized that the increasing population of the city has made imperative a change from the present practice of discharging crude sewage into the water courses, and that it is necessary, in order to protect the public health and to promote the comfort and prosperity of the people, to control the pollution of the water courses by the construction of intercepting sewers and treatment works. Much work to this end has already been accomplished, which is described in the appendix. In laying out new drainage projects in recent years they have been planned with the view that ultimately all of the sewage in the City will require some treatment.

The Legislature of the State of Pennsylvania, recognizing the necessity to protect the public health against water-borne diseases, by an Act approved April 22, 1905, empowered the Commissioner of the State Department of Health to control the discharge of sewage into the waters of the State.[1]

In accordance with these requirements the City of Philadelphia applied for permits to extend the present sewer system, which were granted on April 23d and 25th, 1907, subject to the condition that the city should present in 1914 to the State Department of Health a comprehensive plan for the collection, treatment and disposal of the sewage of the entire city; and that all extensions of the sewer system be in accordance with said plan.

[1] See Appendix A for Act.

Upon recommendation by the Bureau of Surveys and to conform to the requirements of the above Act, City Councils, by Ordinance approved July 20, 1907, authorized the Department of Public Works to make investigations and required it to report on the problem.[1]

In January, 1908, Mr. George R. Stearns, Director, Department of Public Works, and Mr. George S. Webster, Chief Engineer, Bureau of Surveys, were commissioned by the Mayor to visit England and the Continent of Europe to study the methods of sewage disposal then in use. Their report to the Mayor was made under date of February 29, 1908.

In the summer of 1913, Mr. George E. Datesman, Principal Assistant Engineer, Bureau of Surveys, visited the principal sewage disposal works of Europe, and his report is given in Appendix E.

During the investigations, visits were made by officials of the Bureau of Surveys to the sewage disposal works in course of construction or in operation in a number of cities in the eastern part of the United States.

The investigation and preparation of plans have been carried on by the Sewage Disposal Division of the Bureau of Surveys, under the direction of Mr. George S. Webster, Chief Engineer; Mr. George E. Datesman, Principal Assistant Engineer, and Mr. W. L. Stevenson, Assistant Engineer.

Dr. Rudolph Hering, Consulting Engineer, was engaged from time to time for advice.

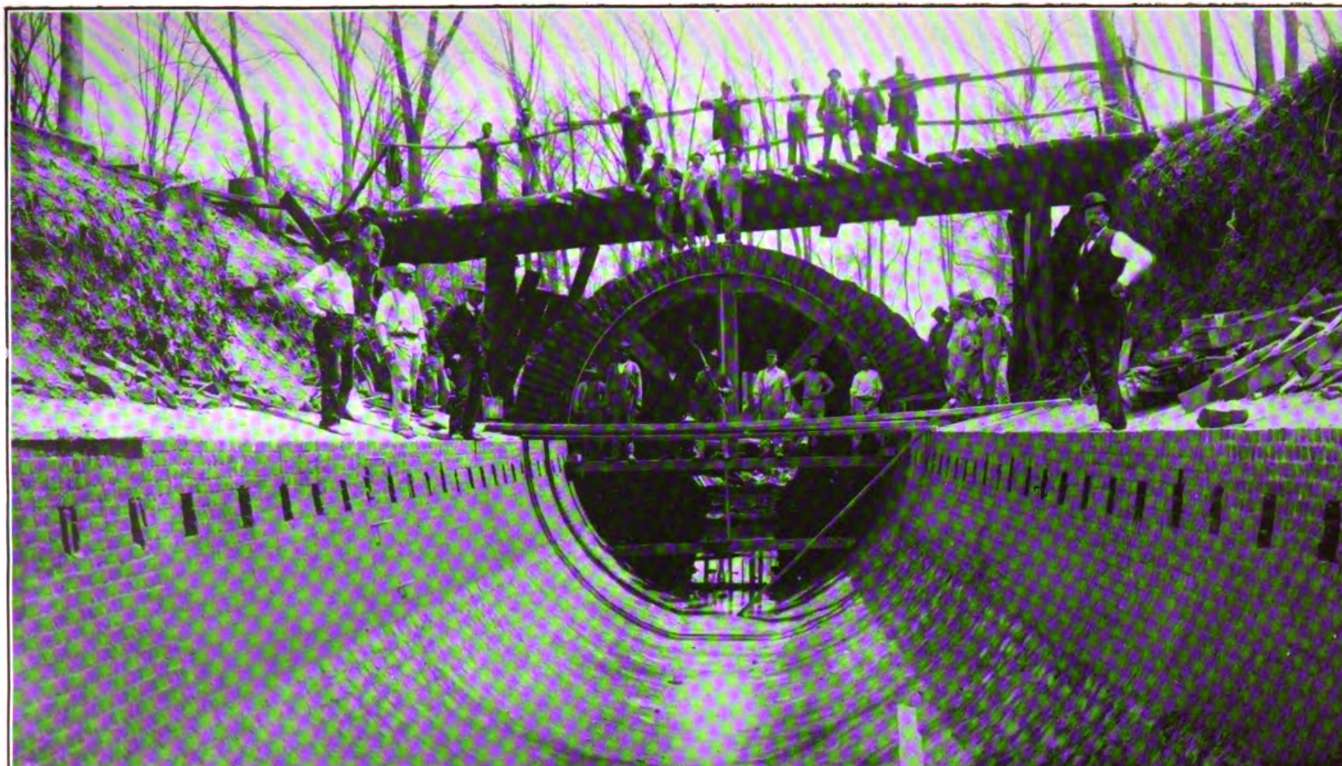
PRESENT CONDITIONS

Population[2]

The U. S. Census of 1900 showed that the population of Philadelphia was 1,549,008. The Bureau of the Census es-

[1] See Appendix A for Ordinance.

[2] For details of the population studies see Appendix B.



Wingohocking Sewer during Construction.

timated that on July 1, 1914, there were 1,657,810 persons in Philadelphia and estimates of the Bureau of Surveys indicate that by 1950 the population will be 3,095,000.

The Water Supply

The water supply of Philadelphia is obtained from the Schuylkill River above Fairmount Dam, and from the Delaware River near the northern (or upstream) limits of the city.

All the water is purified by preliminary and slow sand filters and, in addition, each plant is equipped with a liquid chlorine outfit for use in emergencies.

The water taken from the Schuylkill is purified at the Roxborough, Queen Lane and Belmont filters, and that taken from the Delaware, which provides three-fifths of the city's water supply, is purified at the Torresdale filters.

The good design and efficient operation of these plants provide the city with a superior quality of water which has been a large factor in reducing the typhoid death rate from an average of 60 per 100,000 for 1902 to 1906, to 7.5 in 1914, when all the water was purified.

One hundred and five billion gallons of filtered water were delivered to the citizens of Philadelphia during the year 1913, representing two hundred eighty-eight million gallons a day and one hundred seventy-eight gallons per capita per diem.

The Sewer System

The present sewer system is the result of many years' growth. The earliest sewers were merely drains designed to carry off rain water and to lower the level of the ground water. When water closets were introduced, the house fixtures were connected to these drains and the wastes of domestic life thus conveyed to the nearest water courses. As the population of the City increased and the built-up

territory extended, it became necessary to build sewers for sanitary purposes, and to collect liquid trade wastes. These sewers became tributaries to the early main drains.

The greater part of the present sewer system of Philadelphia is designed for this dual function of carrying both rain water and sewage in the same conduit, which is known as the combined sewer system.

The first kind of work undertaken by the city to prevent the discharge of sewage into the water courses was in 1883, when the construction of an intercepting sewer was begun along the east bank of the Schuylkill River from tide water below Fairmount dam and continued to near the northern boundary of the city, with a main branch extending north along the Wissahickon Creek, having spurs up Monoshone and Cresheim Creek valleys, thus keeping out of the water supply taken from the Schuylkill River all the sewage collected by an extensive system of separate sewers from Manayunk, Roxborough, Falls of Schuylkill and portions of Germantown and Chestnut Hill lying on the Wissahickon and Schuylkill watersheds within the city limits. The rain water from this territory is collected in storm water conduits which discharge directly into the stream.

The second kind of work for the protection of a watercourse was a collecting sewer built along the east bank of Cobbs Creek from tide water northwardly nearly to County Line. This collector passes under each combined sewer outlet and suitable connections between them permit the dry weather flow of sewage and the first flush of rain water to enter the collector, while the excess storm water flows into the creek.

In the illustration of the outlet of the Thomas Run sewer during construction, there is shown the cut stone slot in the bottom of the sewer through which the dry weather flow of sewage and first flush of rainfall enter the cast iron pipe, and are conveyed to the collector.

Outlet of the Thomas Run Sewer during Construction.

Outlet of the Thomas Run Sewer at Cobbs Creek. Sewage being carried by Collector parallel to the Creek.

The photograph of the outlet of the Thomas Run sewer as completed, shows the sewage excluded from the creek. It will be noticed that the bottom of the sewer is entirely dry but during heavy storms the rain water is discharged through this outlet into the creek.

The present sewer system of the city may be divided into three classes:

1. Combined sewer systems carrying sewage and rain water and discharging both into the water courses.

2. Separate sewer systems in which the rain water conduits discharge into the water courses and the sewage sewers discharge into an intercepting sewer parallel to the water courses.

3. Combined sewer systems having transverse collectors for the dry weather flow of sewage and first flush of rain water, while the excess storm water flows on to the water course.

The early drains or sewers were not designed or built in as scientific a manner as they now are, but as the number of miles built per year in those days was small compared with the present, it may be said that the sewer system of Philadelphia is modern, designed and built in a scientific manner, for an examination of the records shows that over 80 per cent. of the main and branch sewers have been built since 1884, about 50 per cent. since 1894, and more than 20 per cent. since 1904. The total length of main, branch, private and miscellaneous sewers up to January 1, 1914, amounts to 1285.7 miles, and represents the expenditure of $35,302,588.38.

During 1910 a survey was made of the older main sewers of the city to determine their physical condition and needs for repairs or reconstruction. The portions of these sewers requiring reconstruction and the estimated costs are given in Appendix B.

In any new project the present sewer system must be considered as a valuable permanent asset; therefore, the proposed collecting sewers should be adapted to the existing system.

For further details of the sewer system see Appendix B.

The Water Courses

Sanitary surveys of the creeks and rivers at Philadelphia have been made to determine the effect upon them of the discharge of crude sewage from the present sewer outlets.

Poquessing Creek

This creek forms the northern boundary of Philadelphia and on its watershed is principally farm land. The waters of this creek are not noticably polluted.

There are no sewers now built on the area, nor is the territory sufficiently developed to require the design of a sewer system. The city owns a large tract of land on this watershed, upon which municipal institutions are being built, and for which a local sewer system and treatment works are being provided.

Pennypack Creek

The condition of this creek above the dam at Frankford Avenue is generally similar to Poquessing Creek. Below the dam there was formerly discharged the crude sewage from Holmesburg, the County Prison and the House of Correction. This caused a serious pollution, and as the creek enters the Delaware River within 2,000 feet of the intake of the Torresdale filters, it was of vital importance to remove this local pollution of the source of the water supply.

Collecting sewers were built along the bank of the creek to gather the sewage and first flush of rain water from

existing sewer outlets, and from the institutions and convey it to a pumping station, where it is screened, passed through a grit chamber and forced to treatment works, consisting of two sedimentation tanks of the Emscher type for the removal of the suspended matter in the sewage, one acre of percolating filters for the removal of the putrescibility of the sewage, a disinfection house where a solution of hypochlorite of calcium is added to destroy the disease germs, and a final settling basin to remove the settleable material which may pass through the prior processes.

The collection of the sewage and the operation of this plant have resulted in restoring Pennypack Creek to a clean condition, and the effluent of the plant, when discharged, is practically free from suspended matter, will not putrefy and contains no disease germs.

Frankford Creek

The upper reaches of this creek are similar to Poquessing Creek and present a clean appearance. Where, however, the Wingohocking Creek joins it, carrying the sewage of 85,000 people, collected by the Wingohocking sewer system from Germantown, the waters of the creek are inadequate in volume to properly dilute the sewage and the creek becomes seriously polluted.

In this condition the creek flows on toward the Delaware River and sewage and trade wastes are continually being added to the already overtaxed water. A dam on the creek causes low velocities of flow, so that heavy deposits of sewage sludge exist on the bed of the creek which, by the putrefaction and decomposition of the sewage matters, add to the polluted appearance of the water. The lower, or tidal part of the creek, is benefited by the refreshing action of the tidal flow, whereby the water of the Delaware River is carried up-stream and helps to dilute the sewage.

Cobbs Creek

A collector has been constructed along the east bank of the creek, through which the sewage of more than half the drainage area tributary to the creek within Philadelphia is carried to the tidal part of the creek. Its present polluted condition is, therefore, largely due to the sewage discharged from the adjoining county.

Schuylkill River

The portion of the river above Fairmount Dam is protected from sewage pollution from Philadelphia by the intercepting sewer described above. Below the dam, however, the sewage of about 500,000 people is discharged into the river; the volume of diluting water is inadequate to inoffensively dispose of the sewage and the velocities of flow are insufficient to maintain the sewage matters in suspension.

As a result the Schuylkill River between Fairmount Dam and its mouth is grossly polluted; sewage matters float upon the surface of the river; the water is turbid and frequently highly discolored, the putrefaction of the sewage matters deposited on the bed of the river causes an almost constant ebullition of gas which, at times, is offensive; at low tide the sloping banks of the lower part of the river are exposed and show the putrefying black mud of sewage origin.

These conditions prevent the attractive development of the banks of the river either for pleasure or business purposes and, as a consequence, there have grown up adjacent to them a number of oil refineries and garbage reduction works.

Delaware River

The Delaware River is one of the large rivers of the United States, and forms the natural drainage for portions of the States of Pennsylvania, New York and New

Delaware River at Arch Street, Philadelphia, from the New Jersey side.

Jersey. The minimum rate of flow of upland water during a month of extreme drought is at a rate of 2,030 second feet; the normal flow during months free from freshet or drought is at a rate of 4,050 second feet.

There is a tidal range of 5½ feet, and it is estimated that during the ebbing of the tide 2,421,000,000 cubic feet of water flow past the city.

The accompanying view was taken from the east or New Jersey side of the Delaware River, and inadequately portrays the size of the river, which is about 2,000 feet wide at this cross section.

In order to observe the effect upon this river of the present discharge of sewage directly from the sewers and indirectly from the creeks and lower Schuylkill, the condition of the water and of the bottom of the river has been very carefully examined and studied; as a knowledge of the present conditions will afford information as to the degree of treatment required for the sewage of the city when it is collected at suitable points for disposal.

Under normal conditions of the Delaware River its water at the northern (or upstream) limits of the city is free from noticeable sewage pollution and presents an attractive appearance. The water at this point contains even in summer sufficient dissolved oxygen to justify its use for the purpose of diluting and oxidizing the effluent from the proposed sewage treatment works.

But the sewage discharged into the river from towns above Philadelphia and that carried up by the flood tide from the city is evident from the almost constant presence in the water of the bacillus coli, as shown in the following table taken from the Report of the Bureau of Water for 1913:

BACTERIA, IN DELAWARE RIVER—TORRESDALE FILTERS, 1913.

Month	Number of Bacteria on Gelatine at 20 deg. C.			Bacillus Coli.						
	Number of test days	Mean per c. c.	Median per c. c.	Number of test days	0.1 c. c. tests			1.0 c. c. tests		
					Total Number	Number Positive	Per cent. Positive	Total Number	Number Positive	Per cent. Positive
January	31	5,300	3,600	13	13	13	100	13	13	100
February	28	4,600	4,400	11	11	7	64	11	11	100
March	31	9,600	4,600	12	12	12	100	12	12	100
April	30	8,200	4,000	14	14	8	57	14	14	100
May	31	6,700	5,200	12	12	11	92	12	12	100
June	30	7,300	2,900	13	13	10	77	13	13	100
July	31	5,000	3,400	14	14	10	71	14	13	93
August	31	9,000	6,200	12	12	11	92	12	12	100
September	30	5,600	4,200	13	13	10	77	13	13	100
October	31	10,000	7,000	13	13	13	100	13	13	100
November	30	8,500	6,200	11	11	11	100	11	11	100
December	31	12,000	7,700	15	15	15	100	15	15	100
Total	365	—	—	153	153	131	—	153	152	—
Average	—	7,680	—	—	—	—	—	—	—	—
Per cent. time	—	—	—	—	—	86	—	—	99.3	—

One of the Outlets of the Cohocksink Sewer System at Laurel Street.

As the river flows past the city it receives the crude sewage of Philadelphia and neighboring communities discharged by the sewers at the banks or into the docks. When the sewers discharge at the shore of the river the sewage does not at once diffuse with the main body of the river, but flows for some distance parallel to the bank. In cases where sewers discharge into docks, sludge deposits are formed on account of the absence of currents to maintain the sewage matters in suspension. The decomposition of these sludge deposits causes gross nuisance to both sight and smell in the vicinity of the piers.

In the accompanying illustration is shown one of the outlets at Laurel Street of the Cohocksink sewer system. It is estimated that sewage from a population of 260,000 people, amounting to 60,000,000 gallons a day, is discharged from this 18 feet 6-inch diameter sewer into the confined dock.

The Delaware River also receives the polluted waters of Frankford Creek and the lower Schuylkill River, which carry respectively the sewage of 140,000 and 500,000 people, and are so polluted that frequently no dissolved oxygen is present in their waters.

The shipping in the harbor also contributes sewage and considerable debris.

Fortunately, the tidal velocities in the Delaware River are sufficient to maintain the solid sewage matters in suspension, and they are progressively carried forward by the tidal movement toward the ocean. The surveys of the bottom of the river at Philadelphia show it to be clean and free from any deposits of sewage origin (except in the docks).

This is of the greatest importance in the utilization of the assimilating and oxidizing capacity of the river, for where sludge deposits exist upon the bed of a stream the

products of decomposition, mingling with the water, are a serious tax upon its oxidizing power and, consequently, proportionately reduce the amount of sewage which the river can inoffensively assimilate.

As a result of the discharge of crude sewage from this and other communities into the Delaware River, its water in front of and below the city has a decidedly turbid appearance, debris and floating sewage matters are seen upon the surface, and during the summer the oxygen dissolved in the water is nearly exhausted, but no nuisance to smell has been noticeable at such times, except in the docks where sewage deposits exist.

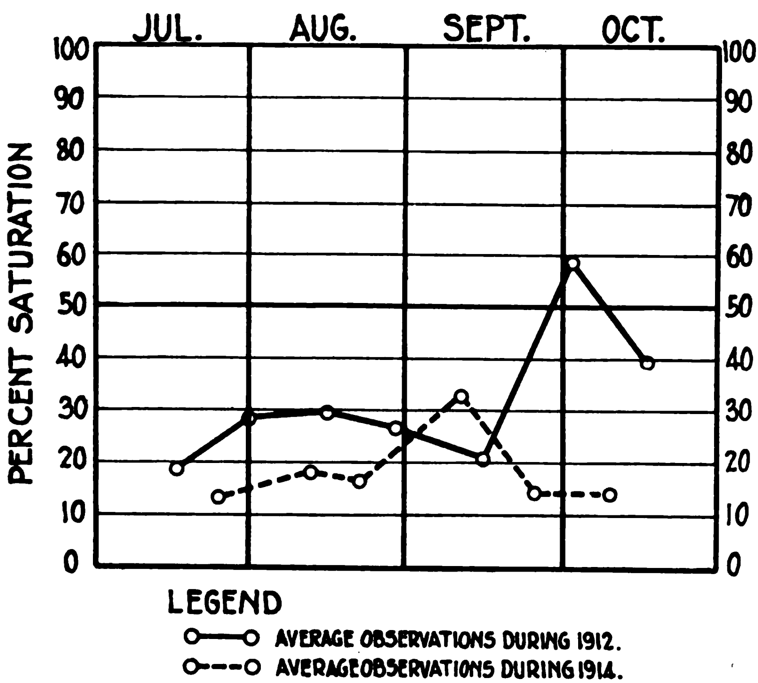
A material decrease in the amount of dissolved oxygen in the water has been noted between the observations made in 1912 and in 1914, as shown in the accompanying diagram.

The reason for this is that while the volume of flow and oxidizing power of the river remain practically the same, the quantity of sewage is steadily increasing each year, due to growth in population, development of industry and consequent extension of the sewer system.

It must, therefore, be emphasized that any delay in constructing the works for the interception and treatment of the sewage of Philadelphia and neighboring communities will result in overtaxing the diluting and oxidizing capacity of the river, which will cause the creation of a nuisance in the river channel, and of greater importance is the danger of jeopardizing the public health by overtaxing the Torresdale filters.

In Appendix D further details of the sanitary surveys are given.

DIAGRAM SHOWING
THE DECREASED AMOUNT OF
DISSOLVED OXYGEN IN THE WATER
OF THE DELAWARE RIVER
AT
ARCH ST. PHILADELPHIA
IN
1914 FROM THAT OBSERVED IN 1912



THE PROBLEM OF SEWAGE DISPOSAL CONFRONTING THE CITY OF PHILADELPHIA

The problem of sewage disposal confronting the City of Philadelphia must be considered from four points of view:

1. The public health.
2. The comfort and prosperity of the people.
3. The development of the port of the City.
4. The economical expenditure of funds.

The Public Health

The collection of the liquid wastes of towns by means of water-carriage in a system of sewers is a modern practice, for while such isolated examples as the Cloaca Maxima of Rome have existed for many centuries, it can be said that practically but little consideration was given to the sewerage problem prior to 1850. Before that time domestic wastes and even faecal matter were allowed to accumulate in proximity to dwellings. Such conditions not only created gross nuisances, but were a serious menace to public health through contamination of wells and transmission of disease germs by insects, the soiling of hands and other means of contact whereby the germs are introduced into the human system.

About the middle of the nineteenth century there arose what was known as the filth theory of disease; it was thought that many diseases actually originated in putrefying filth.

In 1847 there was created in England the Royal Commission on "Health of Towns," the duties of which were to investigate and report to Parliament on the cause of epidemic diseases so common in the towns. As a result of its investigations, laws were enacted which at first permitted and later made mandatory the discharge of domestic sewage into the drains and culverts of the towns. It is now known

that filth is not the cause of disease, but only the vehicle for the transmission of disease germs, and it has been learned that cleanliness is the vital essential of sanitation. No municipal work, except a pure water supply, has a greater effect upon the health and comfort of a community than a properly designed and operated sewer system whereby the filth is promptly removed in underground channels. Such a system makes possible the abolishment of privy wells, which are a menace to public health by pollution of ground water and by transmission of disease germs through flies. It has been stated that in Nottingham, England, over a period of ten years 15 times as many typhoid cases developed in houses with privies as in those having sewer connections.

It was formerly thought that the air in sewers, commonly called "sewer gas," was the cause of many diseases. Careful investigations by sanitarians have shown that this air is really much freer from bacteria than ordinary street air; this is due to the moist surfaces of the interior of the sewer holding the germs, whereas the dry street dust allows them to be carried about by the wind.

The water carriage of sewage was a distinct sanitary advance, inasmuch as it removed the filth of the towns from the dwellings of the citizens, but the discharge of untreated sewage into water courses transferred the nuisance to the streams.

Prior to the discharge of sewage into the water courses they were, according to the standards of that time, fit sources of water supply. But the pollution of the rivers, the increased demand for water supplies, the raised standards caused by the increasing knowledge of sanitation, all acted together to demand the treatment of the sewage and the purification of the water as a protection to the public health.

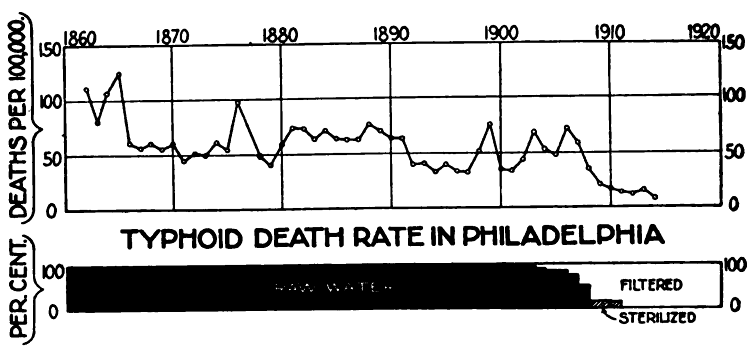
It is now conceded by all sanitarians that surface waters in populated districts are unfit for water supply without

purification, due to pollution from surface washings, occasional and constant pollution from individuals and communities.

Evidence is available to show that the public health is as well, if not better, protected against water-borne diseases (such as typhoid fever) by efficient purification of polluted water, as by the attempted protection from pollution of an impounded supply used without purification.

For example, the City of Hamburg, Germany, obtains its water supply from the Elbe River, which is tidal. Eight and one-half miles below the water intake the screened sewage from 900,000 people discharges through submerged outfalls and the flood tide carries some of the sewage past the water intake. Water filters were installed in 1893, and since 1894 the typhoid death rate of Hamburg has averaged less than 4 per 100,000, reaching as low as 2.7 in 1907.

The filtration of the water supply of Philadelphia has been the principal factor in lowering the death rate from typhoid fever from an average of 60 per 100,000 for 1902-1906, when unfiltered water was used, to 7.5 in 1914, when all the water supply was purified.



To purify sewage to a degree which will render it innocuous to health entails an expense which is not commensurate with the benefits derived therefrom. And further-

more, even if all towns on a watershed were provided with complete sewer systems and sewage treatment works designed to produce sterile effluents, they must be provided with stormwater overflows and emergency by-passes which, at times, allow crude or partially treated sewage to reach the water courses.

The protection to the public health from water-borne diseases can best be obtained by the treatment of sewage to such a degree that the water into which it is discharged can be safely and economically purified, so as to always afford a pure and wholesome water supply. The river water should also be not so polluted but that in times of emergency or shut-downs of the water purification plant it can be temporarily sterilized by calcium hypochlorite or other sterilizing agencies.

Considering the matter in the light of the above, it may be stated that the first part of the problem of sewage disposal confronting the City of Philadelphia is to collect and treat the sewage so as to protect the public health and to prevent undue pollution of the water taken from the Delaware River at the Torresdale Water Filters.

The Comfort and Prosperity of the People

Sewage contains the wastes of domestic life and industrial activity, a considerable part of which is organic matter and, therefore, subject to change in conditions; when sewage is discharged into insufficient volumes of diluting water this change occurs by putrefaction, which is offensive.

The discharge of large quantities of crude sewage at frequent points into the streams and rivers which flow through the city causes deposits, which decay, give forth malodorous gases and create discomfort to the people who live or pursue their various occupations in the vicinity; such conditions also result in the depreciation of property values and make it undesirable to construct manufacturing estab-

lishments along their banks, where the many men and women operatives are compelled to pass the entire day under unpleasant and uncomfortable conditions.

Foully polluted streams flowing through sections of the city convert what might be attractive residential sections into slum districts, where buildings are erected and housing conditions exist which foster unwholesome conditions of living.

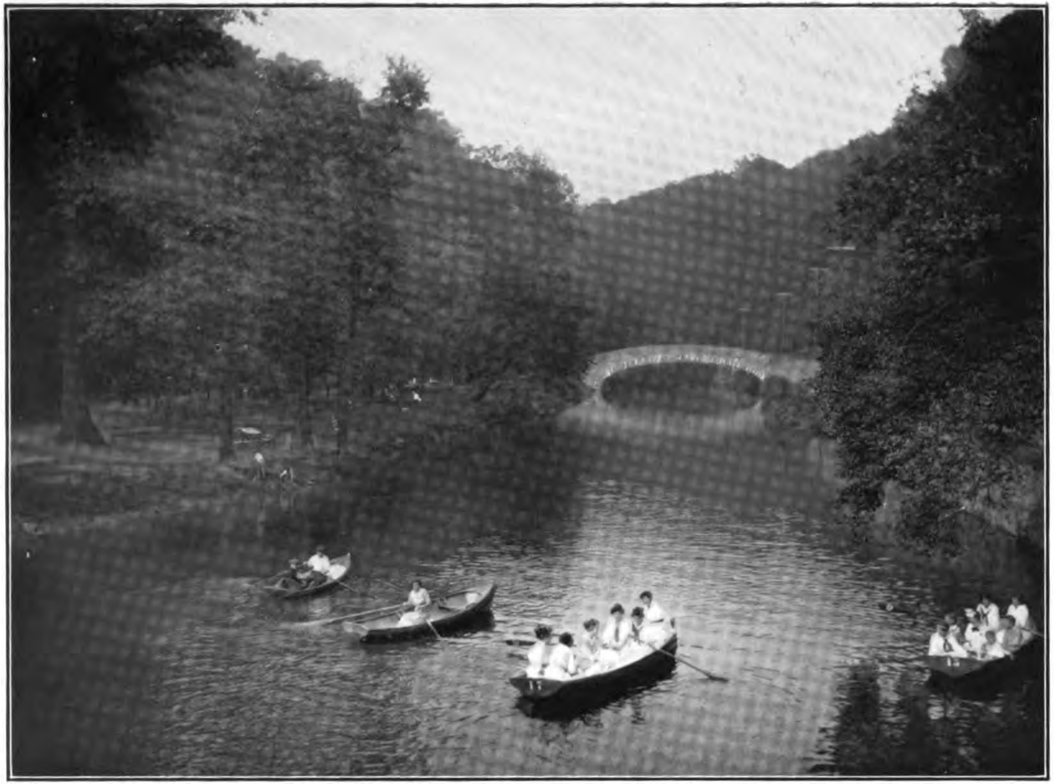
The protection of the upper Schuylkill River and Wissahickon Creek from the sewage pollution of the city has made it possible to maintain the water in these streams in such clean condition that thousands of citizens enjoy exercise and recreation in boating upon them and picnicking with their friends and families upon the beautifully wooded banks. Compare these with the present conditions along Frankford Creek and that portion of Cobbs Creek where the sewage has not been intercepted, and the possibility of attractive development along these latter streams may be comprehended.

The removal of the sewage by the intercepting and collecting sewers will make available the shores of the rivers for commercial purposes and the laying out of attractive boulevards and esplanades; undesirable and insanitary conditions having been removed, the banks of the creeks will then be suitable for development for park and pleasure-ground purposes, all of which will tend to increase the welfare of the city and promote the comfort and prosperity of its citizens.

Development of the Port and City

Philadelphia has long enjoyed the reputation of being the great fresh water port of the Atlantic coast. The United States Government, recognizing its advantages, has established a great Navy Yard at the southern end of the City. Large sums of money have already been expended

Fouling of Frankford Creek by the sewage discharged from the Wakeling Street Sewer.



Wissahickon Creek protected from Sewage Pollution by an Intercepting Sewer.

upon the development of the harbor and of the great commercial avenue along the river front and it is contemplated that the City, the Commonwealth and the National Government will, in the future, make large appropriations to increase the commerce of the port of Philadelphia.

To maintain the reputation of this port and to utilize the improvements to the fullest extent, it is necessary that a high sanitary standard be established and that the channels and banks of the navigable streams shall be kept in decently clean condition.

At the present time, great sewers discharge their foul contents into the docks where there is not sufficient current to carry the sewage away. As a result, many of them are grossly polluted by the decomposition of the sewage sludge, and nuisance to sight is caused by the faecal matter and scum floating on the surface.

When steamships and tugs enter or leave these docks they stir up the deposits upon the bottom, adding to the nuisance, and they lie in this foully polluted water while landing their passengers and loading or unloading their cargoes, which frequently consist of fruit or foodstuffs.

It is, therefore, imperative that immediate steps be taken to intercept the sewage which is now tending to create disgraceful conditions in the docks.

Mr. John D. Watson, Chief Engineer of the Birmingham, England, Sewage Works, in his report to the Metropolitan Sewerage Commission of New York City, speaking of pollution to harbors, makes the following statement:

> "Many years ago the Clyde became so foul that even poor trippers declined to board pleasure steamers nearer to the Broomielaw than Greenock, several miles down the river. Since that time large sums of money have been spent on sewage disposal works, but the bad reputation justly associated with the name of Glasgow harbor years ago will not be got rid of for many years to come."

It, therefore, behooves the City of Philadelphia to prevent the development of similar conditions along the river front; for the correction of such conditions costs far more than their prevention in the first instance.

The magnificent development of the Thames Enbankment at London, the boulevards and esplanades along the banks of the Seine in Paris, and commercial development of the Elbe at Hamburg and Dresden, and the attractive appearance of the Main at Frankfurt, and of the Danube at Vienna, could not have been possible if these streams were as foully polluted as the Schuylkill River is at the present time between Fairmount Dam and the mouth.

The intelligent interception and treatment of the sewage have made possible these developments in foreign cities and have brought a great wealth of commerce to their ports.

It is essential that if our port, in competition with others seeking trade in South America and through the Panama Canal, is to be successful, that all the conditions which go to make a port great shall be found here and one of the most important of these is that the waters of the river shall be clean and the docks into which the vessels enter shall be free from the sleek and slime now discharged into them from sewers along the river front.

The Economical Expenditure of Funds

The whole future of the city, its economic growth, development and maintenance demand the proper distribution of public funds so that each function of civic life will be provided for in proportion to its needs and the benefit that should be derived therefrom.

Modern cities are engaged in a great variety of activities and almost innumerable functions must be provided for in order to conserve the public health, guarantee the safety and promote the comfort and welfare of the citizens.

The funds available should be apportioned so as to obtain

Boat Houses on the bank of the polluted Frankford Creek.

the greatest resultant benefit to the public at large and to the advancement of the commercial and industrial interest of the city.

In recommending expenditures for the construction of intercepting sewers and for sewage treatment works it has been borne in mind that only such expenditures should be recommended as in the light of modern practice and experience, are absolutely necessary. These expenditures are recommended in amount and in progressive order, so that each step in the work shall yield the largest results commensurate with the funds expended, and that in the end the city will have a plant capable of treating the sewage to the extent required and also so designed that it may be extended from time to time to care for the increasing volume of sewage and to provide for a standard of healthfulness which will equal the ideals at that period.

DISCUSSION OF POLICIES

The sanitary surveys showed that sewage discharged into the Delaware River north of Bridesburg is carried by the rising tide some distance north of the intake of the water supply; that sewage discharged into the docks of the Delaware River creates nuisance from sludge deposits; and that the volume of flow in the creeks and Schuylkill River is insufficient to inoffensively dilute the sewage naturally tributary to them.

In order, therefore, to secure sufficient volume to dilute and render inoffensive the liquid wastes, recourse must be had to the great tidal volume of the Delaware River. The logical process will be to intercept the sewage from sewers emptying into the Delaware River and its tributaries by means of collecting sewers, and carry it to the treatment works, and dispose of the effluent by diffusion in the waters of the Delaware River.

Collection

Discussion of Systems

There are two methods, either of which may be adopted, for collecting the sewage of the city to suitable points for treatment:

1. Separate System.

   By means of the installation of a new system of sewers for the exclusive collection of sewage and the utilization of the existing combined sewers for the exclusive collection of rain water; and the installation of the separate system in drainage areas not yet provided with sewers.

2. Combined System.

   By means of the construction of collecting sewers to gather the dry weather flow of sewage and the first flush of rain water from the existing or future combined sewers and the sewage from those parts of the city in which the separate system is now installed.

There are numerous advocates of both systems when discussing them in the abstract. In the adaptability for a city possessing almost 1,300 miles of sewers, for the most part built upon the combined system, the discussion must take into account this important factor.

The introduction of the separate system undoubtedly would have an advantage over the combined system in the matter of collecting the sewage at a more uniform rate and less in amount, would exclude all sewage, even at times of storm, from the water courses, and would lessen the load upon treatment works and prevent possible detriment to their operation due to absence of grit or changing sewage characteristics.

On the other hand, the utilization of the present combined sewers and the extension thereof upon the same plans have decided advantages over the separate system that will outweigh advantages claimed for the former system, when applied to the local case.

They may be stated as follows:

The lifts and consequent pumping costs will be less.

As the first flush of rainfall contains the deposits on the sides of the sewers and the filth from the street surface, it is generally more polluting than the ordinary dry weather flow of sewage. When the combined system of sewers is used this is intercepted and conveyed to the treatment works. Occasionally the rate of rainfall is sufficient to cause overflow at the point of interception but the sewage is diluted with rain water to such an extent that the polluting effect upon the water course is no greater than that from the normal runoff from fields and streets.

The increased fluctuation in flow to the works by the use of the combined system is compensated for by decrease in concentration of the sewage; therefore, it would be susceptible of passage through the works at greater speed.

While the separate system excludes grit, the cost of grit removal at the works necessitated by the combined system is slight as compared with the amount saved in the first cost of the combined over the separate system.

The occupation of less space in the streets, by the single conduit of the combined system instead of the two of the separate system and by one set instead of two sets of lateral house connections, with consequent lessening of interference with the sub-surface structures.

The saving to the property owners alone of approximately $25,000,000, by the use of the combined system, obviating the cost of rearranging plumbing systems to provide double connections required by the separate system. The calculation is based upon 250,000 buildings at $100 per building.

The utilizing of the present combined system and the consequent saving of the cost of the intallation of an additional sewer and possible reconstruction of the existing combined sewer, the length of such sewers approximating 1,300 miles. In addition there would be saved the cost of repaving the streets, all of which work would be attended with inconvenience to traffic and citizens.

After an examination of the collecting systems of the principal cities of Europe, there is found that in no case has the existing combined sewer system been replaced by a separate system, but, on the contrary, in some cases the existing separate system has been replaced by the combined system in urban areas.

The difficulty of policing the connections in a double system, involving improper connections, does not guarantee the exclusion of pathogenic germs from the streams. On the other hand, with a single house connection used in the combined system policing is not necessary, and all of the dry weather flow is sure of delivery at the works for treatment.

After observation of the working of the two systems in foreign cities, where the consensus of opinion is given as against the employment of the separate system in closely built-up urban territory, except in the low-lying areas subject to river overflow, or for the protection of a water supply, and after extensive experience in this City, it has been

deemed advisable to adopt the combined system, or the second proposition mentioned at the head of the chapter, for, in addition to avoiding all of the disadvantages of the first, it utilizes the present sewer system of the City with only minor changes at the points of connection with collecting sewers; the first flush, or as much as may be desired, of rain water can be kept out of the water courses and carried to the treatment works; and the protection of the water courses can be accomplished in much shorter time, due to the fact that as fast as the collecting sewers are built the sewage from each drainage area intercepted is collected without the delay of resewering the entire drainage area, and altering and reconnecting all house drains.

Exceptions are of necessity made to the above policy in low lying areas or where required for the protection of a water supply where the separate system will be installed, described in detail at a proper place.

Design of Collectors

As a detail of the policy to be pursued in the design of collecting sewers it may be stated that a principle will be applied which is a radical departure from the design of similar structures heretofore in use in American cities.

The design of these structures where such collecting sewers have been in operation for a period of years has been worked out in a scientific manner in a number of European cities and the eminently satisfactory results upon the water courses have been observed.

The conditions for constructing collectors abroad were ideal as their grades were made to control and not to be controlled by the grades and therefore the elevations of the tributary sewers at their confluence.

In this city, however, the problem as to the design of collectors is more complex since the main tributary sewers

have been built with outlets at various elevations, and since it is advisable to utilize in its entirety this system of sewers.

The principle in use abroad may be adopted at the expense of some increase in depth of the collectors. The conditions indicated will admit of placing the invert of a collecting sewer at its up-river end slightly lower than the elevation of the invert of the tributary combined sewer and of carrying the collector through a dam to be used for diverting to the collector the dry weather flow and for excluding tide-water, located at a point in the tributary sewer where the crest of said dam shall not be higher than two-thirds the vertical diameter of the tributary sewer.

The declining grade of the collector will carry it at an increasingly lower elevation across the succeeding intercepted tributary sewers, thus admitting of the lowering of the dams progressively until the collector will be completely beneath the inverts of the remaining tributary sewers.

The restricted water area in the tributary sewer at a dam would be compensated for by enlarging the section of the sewer at this point sufficiently to accommodate the excess storm flow beyond that which would be taken into the collector and allow the passage of this excess quantity over the dam and into the river.

The principle involves the placing of a separate sewer system over low-lying areas subject to tidal inflow between the dam and the river bank.

The principle is adopted for the reason that by the raising of the collecting sewers in ground which is water bearing of from 5 to 8 feet and in some instances 10 feet above the profile which must be followed in case the usual American practice is adopted, reduces the first cost of such construction by a considerable amount. If placed several blocks back from the river, it will become shallower on account of the ascending grade upon the main sewers and will admit of the house drainage from the river front being

carried backward into the main interceptors, and reduces to a minimum the area that would be required to be sewered upon the separate or double system.

The application of this principle will proportionately lessen the lift required of pumps and consequent permanent maintenance cost and will raise the head on any siphon which may be put into the line.

The most appreciable advantage in the adoption of this principle in the design of collecting sewers is the ability to operate the system without the construction of expensive tidegates, the satisfactory operation of which would be doubtful and the use of which might possibly cause a surcharge of the works or render them ineffective in their operation.

Regulators

The diverting dams also permit the use of a gate regulator without moving parts of complex mechanical arrangement and thus avoid structures liable to break down or requiring constant and expensive maintenance.

A steel gate hung upon a trunnion eccentrically as to the axis has been designed to be introduced in the connecting channel between the main and collecting sewers, depending only upon the rise of the water in the main sewer to exclude the excess during storms, shutting positively by impact and opening by the eccentric weight of the gate itself when the water subsides.

In the opened condition the gate allows only the first flush of the rain to pass to the works in addition to the dry weather flow and in the closed condition it allows no more to pass through the restricted area under the increased head of water in the main sewer.

This will result in a lesser variation of flow to the works under all conditions and will effectively prevent the surcharge of the works or ineffective operation due to the great

diluting volume of storm water which would otherwise reach them.

High and Low Level Collectors

Wherever practicable, it is the purpose to construct two levels of collectors, of which the high levels will collect sewage from areas sufficiently high to deliver the sewage to the works at an elevation not requiring pumping, and thus utilize the potential energy in every foot of head, and the low levels to collect sewage from areas too low for the gravity flow and leading either to local pumping stations to lift the sewage into the high levels or to central pumping stations at the treatment works.

A further advantage of the two levels of collecting sewers is that the quantity of sewage discharged into the water courses can be reduced by the high level collectors for a term of years at a small annual charge for maintenance due to the postponement of the construction of pumping stations, and thus delay the need for the low level collectors for several years and the accumulated annual savings will largely help to pay for their construction.

The present sewer system of the city, with its future extensions and the projected system of intercepting and collecting sewers to convey the dry weather flow and first flush of rainfall to the treatment works, will constitute the most important part of the entire project for sewage disposal, in that their functions of conveying the liquid wastes of the city inoffensively from the points of origin rank, from a sanitary standpoint, even higher than sewage treatment.

Upon the proper design, construction and maintenance of the collecting system will depend also the ability to operate the sewage treatment works without offence.

As has been shown, the early sewers were not as well built as those of modern construction, and some of

them have considerable deposits within them which should be removed. The sewers constructed in recent years have straight grades and smooth interior surfaces. All sewers and the collectors in the future should be built in this way, so that the sewage flowing at velocities sufficient to maintain solids in suspension, a condition obtained by smooth interiors, may serve to prevent lodgment therein of organic matter.

Maintenance of the sewer system and of the collectors to be built is absolutely necessary. In Europe it is a common practice to have the sewers regularly cleaned of any deposits, which may occur at times even in well constructed sewers. This prevents putrefaction and causes the sewage to be delivered to the treatment works in as fresh a state as possible, thereby forestalling offence.

Amount of Sewage Flow Affecting Design

In the design of sewers for the purposes of carrying sewage only, the factors used are the contributing population, water consumption and the amount of infiltrated ground-water. It is quite common practice in many cities in designing sewage sewers to calculate that they shall run half full when carrying a water consumption of 150 gallons per capita from the population tributary.

To reach a conclusion as to the quantity of sewage to be treated by the City of Philadelphia in the future, and to obtain data for the design of the collecting sewers, gaugings were made of the dry weather flow of a number of main sewers, some of which were located in solidly built-up areas and others in partly built-up districts, and from the factors thus obtained estimates were prepared based upon the probable increase and density of population, of the quantity of sewage that must be cared for in the future, the estimates and population curves being projected to the year 1950.

The amount of sewage flow determined by the gaugings in all cases included the infiltrated ground water, no practical way appearing by which it could be separated from the sewage proper. As a majority of the sewers in which gaugings were taken are of considerable size and length, the variation between the maximum, minimum and average rates of flow is not as great as in smaller sewers. The mean of all the gaugings showed that the maximum flow was 128 per cent. of the average and the minimum 78 per cent. of the average. In the accompanying diagram the results of the gaugings of some of the more important sewers are shown.

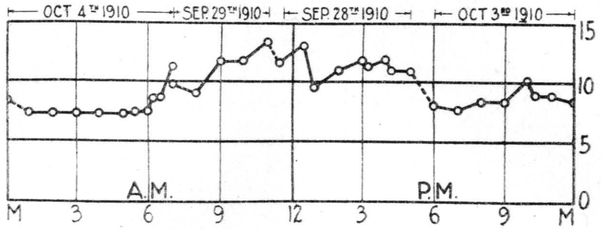
In addition to the flow of sewage, it has been decided to admit into the collecting sewers, through automatic regulators, the first flush of the rain, which is usually as polluting as the sewage, and the amount to be admitted has been fixed at 10 per cent. of the maximum dry weather flow of the sewers, but a much larger percentage can be intercepted when the sewage is not flowing at a maximum rate. This additional 10 per cent. makes a storm maximum flow of 141 per cent. of the average flow.

In England the authorities are required to receive storm water in the regular treatment works until the flow amounts to three times the normal dry weather flow of sewage. Between three and six times the flow must be partially treated in special storm water works and above six times is allowed to overflow to the water course. This provides for overflowing sewage when diluted with five times its amount of rain water.

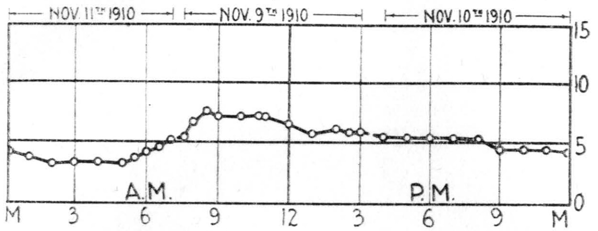
When it is considered that the per capita consumption of water in Philadelphia is 178 gallons a day, and that in the towns of England only about 35 gallons are used, it will be seen that by the arrangement proposed the degree of dilution of the sewage, in time of storm, compares well with the English practice of allowing sewage diluted to

DISCHARGE IN CUBIC FEET PER SECOND

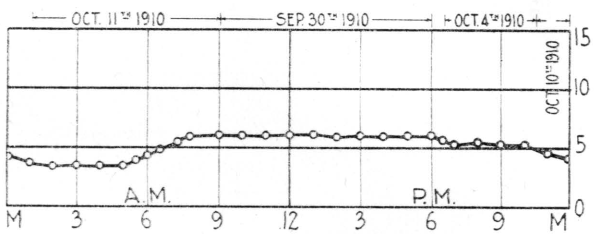
THOMAS RUN SEWER
COBB'S CREEK OUTLET



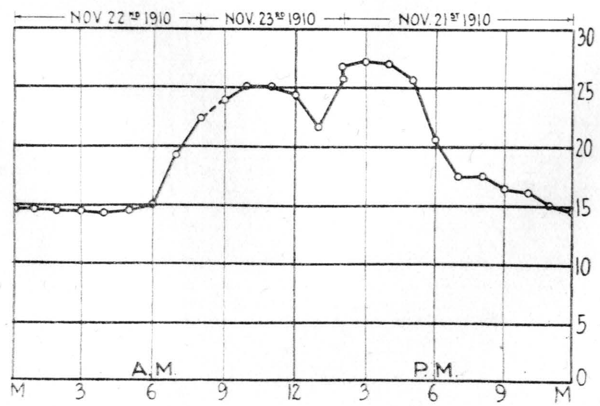
THOMAS RUN SEWER
CONESTOGA STREET SOUTH OF PINE STREET



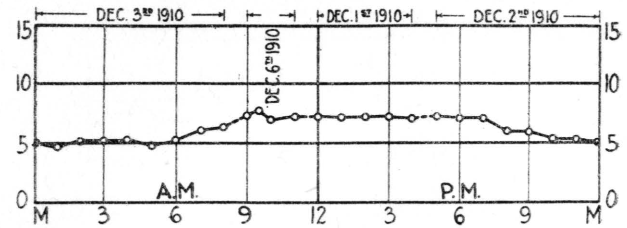
THOMAS RUN SEWER
PINE STREET WEST OF CONESTOGA STREET



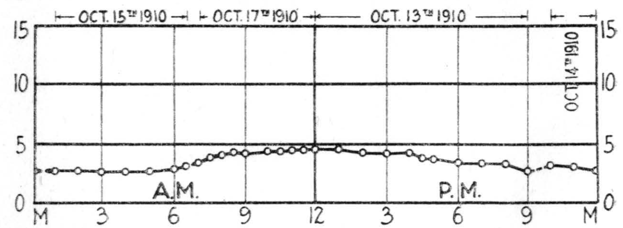
YORK STREET SEWER
AT CEDAR STREET



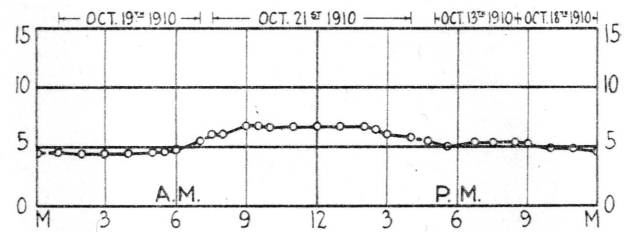
PINE STREET SEWER
BETWEEN 25TH AND 26TH STREETS



SHUNK STREET SEWER
AT BANCROFT STREET



SHUNK STREET SEWER
WEST OF 18TH STREET

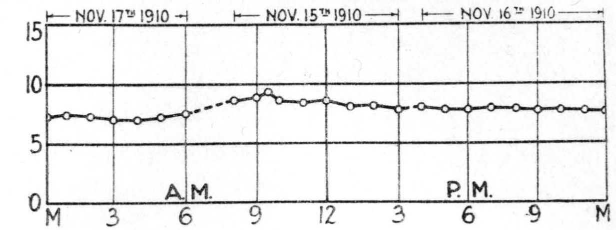


SUMMARY OF DATA
OBTAINED FROM GAUGINGS OF THE DRY WEATHER FLOW
MADE IN 1910

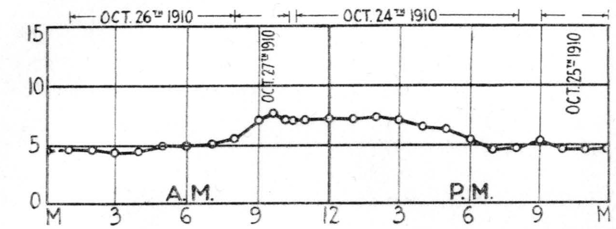
NAME OF AREA	CHARACTER	POINT GAUGED	AREA IN ACRES		POPULATION CENSUS 1910		AVERAGE DISCHARGE PER 24 HOURS					
							GALLONS PER DAY			CU. FT. PER SEC.		
			TOTAL	SETTLED 1910	TOTAL	PER SETTLED ACRE	TOTAL	PER SETTLED ACRE	PER CAPITA	TOTAL	PER SETTLED ACRE	PER CAPITA
THOMAS RUN	RESIDENTIAL MOSTLY PAIRS OF TWO AND THREE STORY HOUSES	PINE ST W. OF CONESTOGA	320	240	15012	62.5	3,410,000	14200	227	5.26	.0220	.000350
		CONESTOGA ST. S. OF PINE ST	426	337	21677	64.0	3,320,000	9860	153	5.14	.0153	.000237
		OUTLET AT COBB'S CREEK	1094	627	36336	58.0	6,175,000	9850	170	9.60	.0153	.000265
PINE ST.	RESIDENTIAL MOSTLY SOLID FOUR TO SIX STORY HOUSES	PINE ST. BETWEEN 25TH AND 26TH STS.	160	156	15152	97.0	4,105,000	26300	271	6.35	.0407	.000419
SHUNK ST	RESIDENTIAL MOSTLY ROWS OF TWO AND THREE STORY HOUSES	SHUNK ST AT BANCROFT ST	208	208	25754	123.0	2,190,000	10500	85	3.39	.0163	.000132
		SHUNK ST W. OF 18TH STREET	331	331	37916	114.0	3,516,000	10600	93	5.44	.0164	.000143
LOMBARD ST	RESIDENTIAL TENEMENTS AND HOTELS	LOMBARD ST. AT THIRD ST.	147	145	16363	113.0	5,030,000	34750	308	7.78	.0536	.000475
YORK ST	RESIDENTIAL AND MANUFACTURING	YORK ST AT CEDAR ST	358	354	33340	94.0	12,754,000	36000	383	19.70	.0556	.000591
MARKET ST.	COMMERCIAL	SOUTH SIDE W OF STRAWBERRY ST	58	36*	THE POPULATION CONTRIBUTING SEWAGE IS NOT SHOWN BY THE CENSUS FIGURES		3,547,000	99250		5.50	.1534	
		NORTH SIDE AT BANK ST	123	80*			7,608,000	92800		11.80	.1435	

* THIS AREA PRACTICALLY ENTIRELY BUILT UP.
* THE SETTLED AREA IS "TOTAL" MINUS STREET AREA

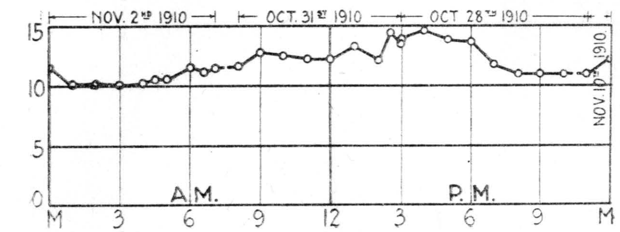
LOMBARD STREET SEWER
AT THIRD STREET



MARKET STREET SEWER
SOUTH SIDE WEST OF STRAWBERRY STREET



MARKET STREET SEWER
NORTH SIDE AT BANK STREET



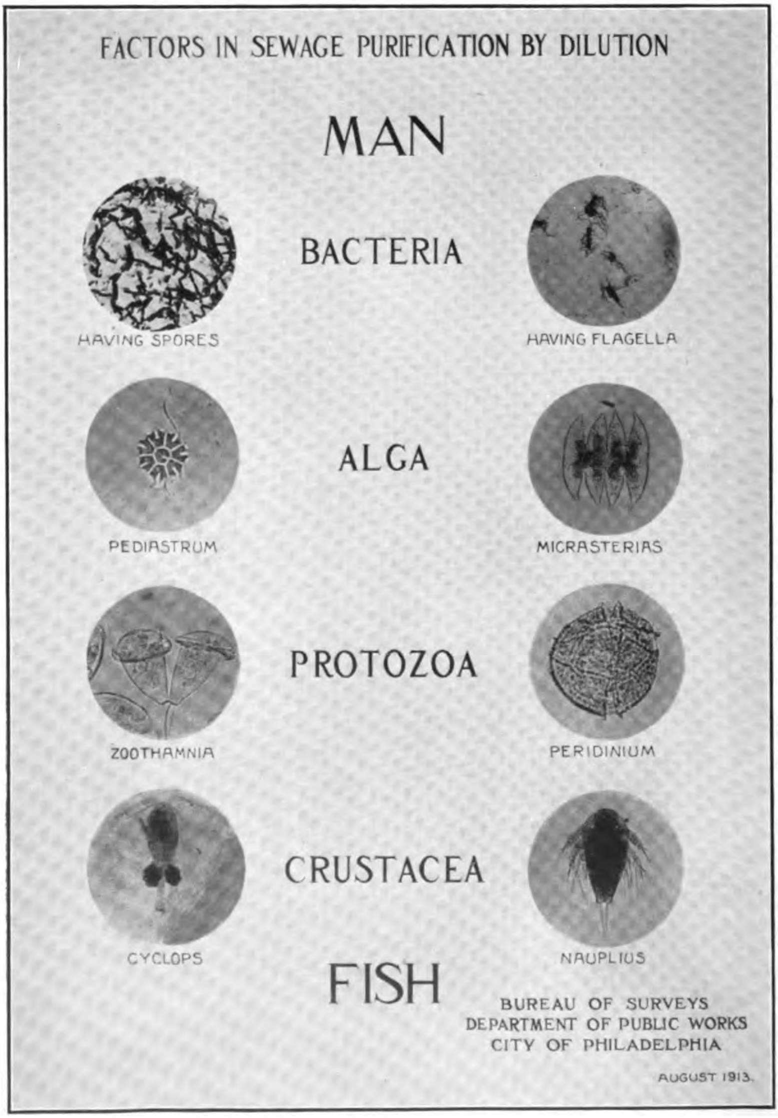
DISCHARGE IN CUBIC FEET PER SECOND

CITY OF PHILADELPHIA

PLAN FOR THE COLLECTION, TREATMENT AND DISPOSAL OF SEWAGE

GAUGINGS OF THE DRY WEATHER FLOW OF SEWAGE

DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
1914


FACTORS IN SEWAGE PURIFICATION BY DILUTION
MAN
BACTERIA
HAVING SPORES
HAVING FLAGELLA
ALGA
PEDIASTRUM
MICRASTERIAS
PROTOZOA
ZOOTHAMNIA
PERIDINIUM
CRUSTACEA
CYCLOPS
NAUPLIUS
FISH
BUREAU OF SURVEYS
DEPARTMENT OF PUBLIC WORKS
CITY OF PHILADELPHIA
AUGUST 1913.

six times the normal dry weather flow to flow to the streams.

Velocity of Flow

In the design of the collectors, grades and cross sections have been used so that under estimated daily average flows the velocity of the sewage will not be below 2½ feet per second.

Treatment

The disposal of sewage by dilution in volumes of water adequate to prevent nuisance is a recognized scientific method. Nature has provided the necessary oxygen, bacteria, and higher forms of life in the water courses to effect the ultimate purification of the decomposable constituents of sewage in an inoffensive manner provided that the biological laws involved are not violated. When the demands of the sewage upon the oxygen of the river water are less than the rate at which it is replenished from the air and other sources, then oxidation will proceed; but when the demands are greater, the oxygen will become exhausted and putrefaction with its accompanying foul conditions will develop.

The biological factors involved in the natural purification of sewage by dilution in water courses shown in the accompanying illustration are as follows:

The first agency are the the bacteria, certain forms of which in their vital processes convert the organic nitrogen of the wastes of man into nitrates, through the steps of free ammonia and nitrites. The necessary oxygen for these changes is obtained from the dissolved oxygen present in the water.

Other types of bacteria cause a combination between the carbon of the sewage and hydrogen to form methane, and still other types of bacteria effect a combination between

the carbon of the sewage and oxygen to form carbon-dioxide. In both cases the dead organic matter is converted into stable mineral matter.

Another function of the bacteria is the liquefaction of solid particles of sewage matter, thus preparing it for further biological action.

The second agency are the algae. These consist of a membrane enclosing a plasm, containing chlorophyll and albuminous material. Under the influence of sunlight algae have the power of disassociating carbon from the carbon-dioxide which is present in the water as a result of the aforementioned bacterial activity. The carbon thus separated is combined with nitrogen to form albuminous plasm and the oxygen is liberated in a nascent state and becomes valuable for oxidation purposes.

The algae, therefore, convert dead organic matter into living organic matter and also liberate oxygen which is necessary for the activity of the bacteria.

The third agency are the protozoa, which utilize as their food supply the bacteria or algae and possibly unconverted dead organic matter.

The fourth agency are the crustacea, which find their food supply in the protozoa and algae.

The economic solution of the sewage disposal problem requires that these natural processes shall be used to the maximum compatible with safety, and the artificial treatment of the sewage reduced to a minimum in order to avoid undue expense for construction and operation of works.

Also in selecting processes for the treatment of the sewage of the city their adaptability to a comprehensive plan is of vital importance in order that the treatment works may be constructed in successive steps as needs arise for more refined treatment. The processes selected should be the most intensive of their kind, so as to secure the maximum of

efficiency upon the minimum area of land and at the least expense for operation and maintenance. They should also be processes which experience in other cities has shown are the least liable to produce nuisance from bad odors.

The solids in sewage exist in four states, *i. e.,* as

1. Floating matter such as faeces, pieces of food, paper, matches, corks, leaves and other objects lighter than water.
2. Solid particles heavier than water, but kept in suspension by the velocity of the current either in the sewer or in the water course. These particles vary in size and composition and are spoken of as settleable matter.
3. Organic matter in a colloidal state, or in such a fine state of sub-division that the particles are microscopic in size and will not settle out even if the sewage be maintained in a quiescent state.
4. Sewage matters in solution, such as the soluble part of faeces, urine, albumen, liquid part of trade wastes, etc.

Available processes of sewage treatment may be divided into classes as regards their function in removing these four states of the sewage matter, such as preparatory or the removal of floating and settleable matter and oxidizing or the conversion of the decomposable organic matter into stable compounds. No clear line separating them can be defined as the functions frequently overlap.

The floating debris can be removed by means of screens with openings varying in size from 6 inches to 1-25 inch or less. The finer mesh screens will also intercept a large part of the settleable matter.

The settleable matter may also be removed by means of tanks through which the sewage is passed at such a

velocity that the solids heavier than water subside to the bottom of the tank and the clarified liquid only flows off.

The decomposable matters existing in a colloidal state or in true solution are converted to stable forms by means of oxidation through the agency of beneficent bacteria and the oxygen of the air or water.

Sewage Farms

The earliest method used for the treatment of sewage was its application to land laid out with main and branch distributing channels so that the sewage could be applied to the different parts of the farm in rotation. In some cases underdrains were laid to collect the water which percolated through the soil. This method was very much in vogue in 1860. Paris adopted sewage farms in 1865 and Berlin in 1876. These are the two largest sewage farms in the world, the former amounting to over 12,500 acres and the latter to 43,000 acres.

The ideal land for the purpose is a light sandy soil supported by gravel to facilitate rapid percolation. The rates of application of the sewage vary between 3,000 and 25,000 gallons per acre a day, and averaging about 10,000, or one acre of land can receive the sewage from 30 to 250 persons.

One of the objects in applying sewage to land was the hope of the recovery of the manurial value of its constituents. But such a large part of the sewage matters are inert, and those having fertilizing value are such a small percentage of the volume of the sewage due to the water carriage of the solids that while some value does exist it is similar to the gold in the clay deposits of Philadelphia, which would cost more to extract than it is worth.

Sir Maurice Fitzmaurice, late Chief Engineer of the London County Council, stated in connection with the utilization of the sewage of the city: "Several enthusiasts on

the subject of the useful utilization of sewage have begged for a sample gallon of it at the outfalls, and one even took away a barrelfull, but I never again heard from any of them, and the amount of sewage which they have taken away has made no appreciable diminution in the 280,000,000 gallons a day which are still at the disposal of anyone who will take it in whole or in part."

With present knowledge, it is not possible to recover economically the small fertilizing value in sewage. If, in the future, means are devised for its recovery, the concentration of the sewage of Philadelphia to the three proposed treatment works will facilitate such recovery.

The Metropolitan Sewerage Commission of New York City has estimated that 175 square miles of land would be required to treat the sewage of that city, and that the cost of this method of treatment would be $153,000,000, and, therefore, dismissed it as impractical, which view was supported by all the eminent experts who reported on their projects.

The City of Birmingham has abandoned its sewage farm, which was one of the largest and best managed in England, and substituted the more intensive biological processes and the same course will probably be followed in Paris.

Mr. John D. Watson, after years of experience at Birmingham, aptly states that this method of disposing of sewage "may be ideal in theory, but it is difficult, if not impossible, to obtain the ideal on the farm of large size."

To treat at the present time the sewage of Philadelphia on farm land would require an area of approximately 60 square miles, and in 1950 of over 100 square miles.

To secure this amount of land in Pennsylvania adjacent to the city would be prohibitive on account of cost, would destroy the highly developed suburbs of the city, and would be opposed by citizens and property owners; hence this method of treatment need not be further considered.

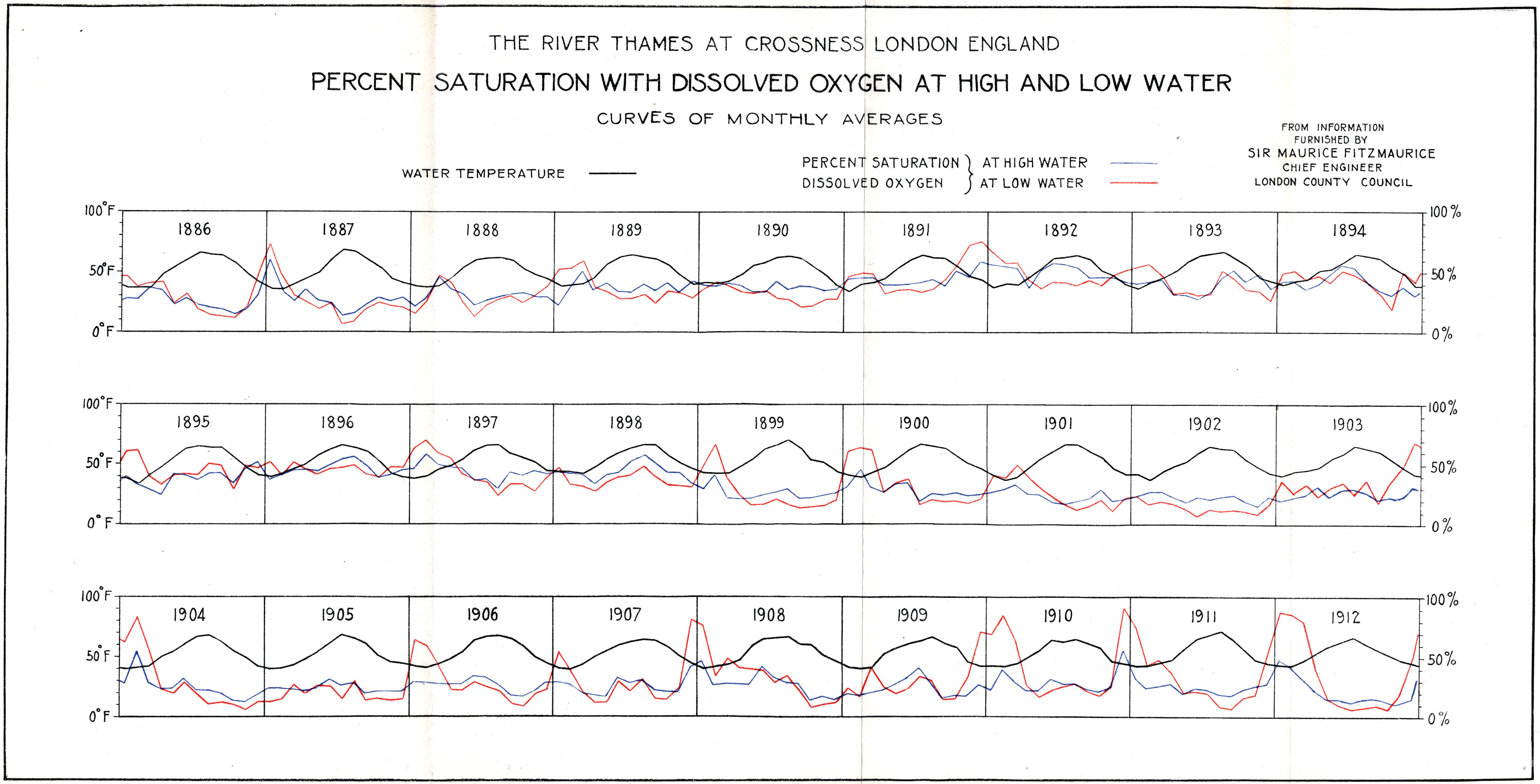
Chemical Precipitation

The next process devised for sewage treatment was called chemical precipitation. It was found by experience that the application of crude sewage to the farms of that day was inadvisable, and that higher rates could be obtained if the suspended matter were removed.

The sewage was, therefore, passed through large tanks in which the velocity was very low, and the sewage retained many hours. Solutions of lime, salts of iron, alumino-ferric or other chemicals which form a flocculent precipitate were added to the sewage before it entered the tank and aided materially in the removal of the suspended matter. The deposit which forms on the bottom of sedimentation tanks is called sludge, and its handling and disposal are described later.

London, the largest city in the world, with a population of 6,000,000 situated on the banks of a river with but little larger flow of upland water than the Schuylkill, disposes of its sewage by removing about 75 per cent. of the suspended matter by chemical precipitation and depends upon the oxdizing power of the great tidal volume of the Thames for the ultimate purification of the dissolved impurities in the tank effluent.

In the accompanying diagram red and blue lines respectively show monthly averages of the percentage of saturation in the dissolved oxygen of the Thames River near the sewage outfalls at high and low water. Attention is called to the small amount of dissolved oxygen in the river water during the summer time, the curve for the year 1912 being quite similar to the curve showing dissolved oxygen in the water of the Delaware River at Arch Street, Philadelphia, during the same year. Notwithstanding the fact that dissolved oxygen in both the Thames and Delaware Rivers reached points below 10 per cent. saturation, no nuisance to smell was caused by the water of either river at such



THE RIVER THAMES AT CROSSNESS LONDON ENGLAND
PERCENT SATURATION WITH DISSOLVED OXYGEN AT HIGH AND LOW WATER
CURVES OF MONTHLY AVERAGES
FROM INFORMATION FURNISHED BY SIR MAURICE FITZMAURICE CHIEF ENGINEER LONDON COUNTY COUNCIL
WATER TEMPERATURE
PERCENT SATURATION DISSOLVED OXYGEN
AT HIGH WATER
AT LOW WATER
100°F
50°F
0°F
100%
50%
0%
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912

times. The City of London has acquired 750 acres of land near the present chemical precipitation works, anticipating more refined methods of sewage treatment being required to maintain the Thames in a clean condition.

While this method is successfully used in London, it would not be applicable to Philadelphia on account of the cost of chemicals, the large quantity of sludge produced, the long haul to dispose of it in the ocean—over 100 miles distant from Philadelphia, and the odors which are produced at such plants.

Septic Tanks

These consist of sedimentation tanks of capacity sufficient to hold from 8 to 24 hours' flow of sewage, the purpose of the long retention being the deposition of the suspended matter, the decomposition of the resultant sludge and the breaking down by processes of putrefaction of the organic sewage matters as a preparatory process to their subsequent oxidation.

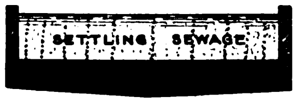
In 1896, when this method of sewage treatment was introduced, it was claimed that nearly all the organic matter deposited as sludge would be gotten rid of and only the inert mineral substances remain. As the sludge from chemical precipitation had proved to be such a troublesome matter, sanitary engineers hailed this idea as a panacea for the sewage problem, and it was rapidly introduced. Experience has shown that the original claims were very exaggerated, and that the long retention of the settling sewage in contact with the decomposing sludge produces a foul-smelling effluent, and that the gas bubbles constantly rising from the sludge seriously interfere with effective sedimentation.

Emscher or Imhoff Tanks

The first attempt to obviate this fouling of the effluent was the digestion of the sludge in a separate tank. Another

SEPTIC TANK

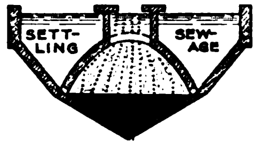
ALL SEWAGE IN
CONTACT WITH SLUDGE



SEWAGE RETAINED
8 TO 24 HOURS

TRAVIS TANK

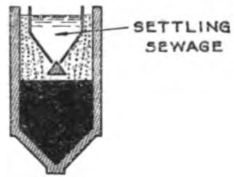
20% SEWAGE IN
CONTACT WITH SLUDGE



SEWAGE RETAINED
5 HOURS

IMHOFF TANK

NO SEWAGE IN
CONTACT WITH SLUDGE



SEWAGE RETAINED
1 TO 3 HOURS.

DIAGRAM
SHOWING THE PRINCIPLES
OF THE
SEPTIC, TRAVIS AND IMHOFF TANKS

CITY OF PHILADELPHIA
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
SEWAGE DISPOSAL DIVISION

attempt was made by Dr. Travis at Hampton, England, who built a septic tank divided into upper and lower compartments; four-fifths of the sewage was passed through the upper part and the sludge settled through slots into the lower part through which the remaining one-fifth of the sewage flowed. Thus four-fifths of the sewage remained fresh, but when the foully contaminated one-fifth was added to the tank effluent it frustrated the purpose. Furthermore, the passage of sewage through the lower part maintained conditions favorable to the development of sulphur bacteria and produced a malodorous sludge.

In the accompanying cut is shown how all the settling sewage in a septic tank is contaminated by the decomposition of the sludge; how one-fifth of the sewage which flows over the decomposing sludge in a Travis tank is fouled; and how the complete separation of the settling sewage from the decomposing sludge in an Imhoff tank maintains the original freshness of the sewage.

The separation of the settling sewage from the digesting sludge was adopted by Dr. Imhoff, of Essen, Germany, with the following essential modifications:

The slot between the upper and lower compartments was so made that the gas bubbles formed in the decomposing sludge could not rise into the settling sewage.

No sewage was allowed to flow through the lower or sludge chamber.

The walls of the lower chamber were carried through and above the water surface of the upper compartment so that the gas could have a free vent, the capacity of the lower chamber made sufficient that sludge could be retained as long as six months before withdrawal.

Two-story tanks of this type are known as Emscher or Imhoff tanks. Their extensive introduction in Germany and America is due to the fact that when properly operated they efficiently free the sewage of its settleable solids, yield

a fresh inodorous effluent, produce sludge that is inodorous, of low water content and consequent small bulk, and which dries more quickly than any other kind of sewage sludge.

The principles involved in the construction of the Emscher tanks are shown in the accompanying cut. The sewage to be settled flows longitudinally through the tank in the cross-section marked A; the solids which settle upon the sloping bottom B slide down through the slots C into the sludge chamber D. The gases of decomposition are prevented from entering the upper chamber by the gas baffle E, but find free exit through the sides at F, in which a scum generally forms. A pipe G extends from the bottom of the sludge compartment to the outside. A quick opening valve at H, located at a distance of over 3 feet below the water surface in the tank, permits the discharge of the digested sludge by hydrostatic pressure without any pumping.

In septic tanks the sewage is retained from 8 to 24 hours; in sedimentation tanks from which the sludge is removed before ebullition of gas from the sludge becomes violent, the retention is from 4 to 6 hours; but tanks built on the two-story principle described above are capable of removing a higher percentage of settleable matter from the sewage in retention periods of from 1½ to 3 hours.

The maintenance of the settling sewage in a fresh condition, and the greatly reduced superficial area required for such installations more than compensate for the higher cost of construction.

The quality of sludge obtained from Emscher tanks will be described later.

Fine Screens

In Germany the preparatory treatment of sewage has been developed to a very high degree not only in the tankage of sewage, but also in removing the suspended solids by means of screens. In many German cities the sewage

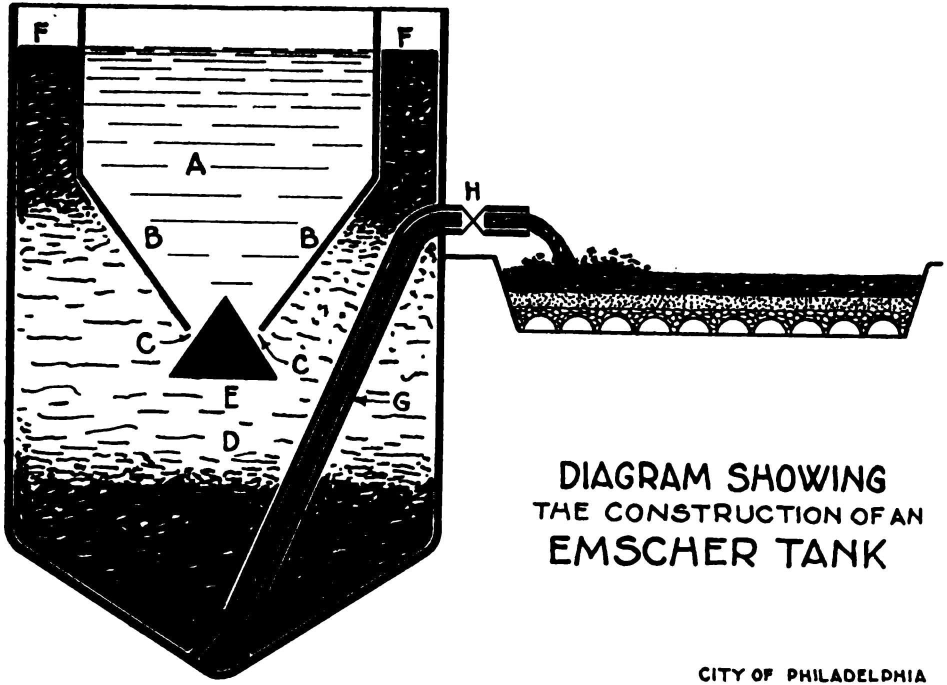


DIAGRAM SHOWING
THE CONSTRUCTION OF AN
EMSCHER TANK

CITY OF PHILADELPHIA
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
SEWAGE DISPOSAL DIVISION

is collected to central points, passed through grit chambers and screens having sufficiently small openings to remove practically all appreciable sized solids and disposed of by diffusion in the river water through submerged outfalls.

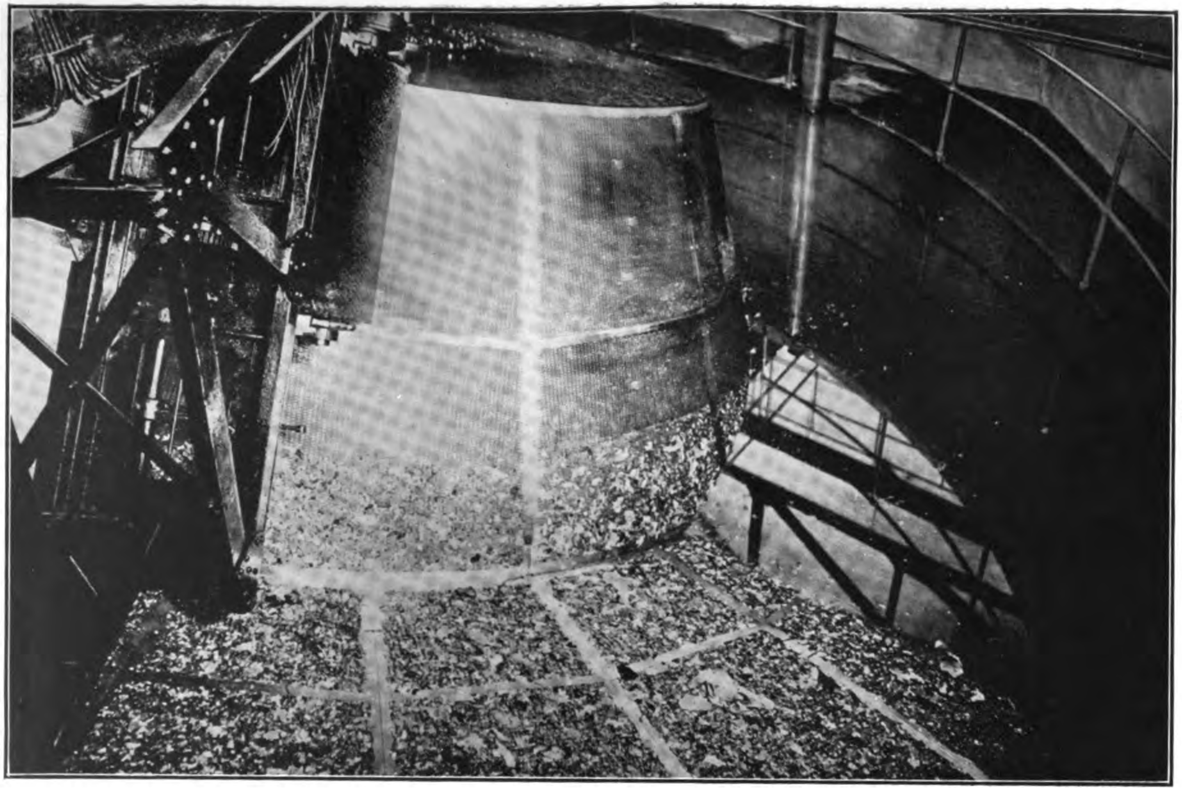
Such treatment works are more compact than those using any other processes. No deep excavation for tanks is required and, where necessary, the screenings can be incinerated at the plant, thereby eliminating the need for sludge drying beds required for tank treatment.

At Dresden, for instance, 26,500,000 gallons a day of sewage are passed through screens, one of which is shown in the accompanying illustration, having openings 1-12 inch wide and 1 1-5 inch long before discharge into the river Elbe. The building required is 85 feet x 230 feet in plan, and the foundations are 12.5 feet below the water level in the sewer. A similar capacity treatment works consisting of Emscher tanks and sludge beds would occupy a space of 150 feet x 500 feet and 30 feet below the water level in the sewer.

The tank installation would remove a larger percentage of the suspended solids in the crude sewage than the fine screens, but there are circumstances where the oxidizing power of the river water can be utilized for the assimilation of the fine particles passing through the screens.

Such a condition will exist at the proposed southeast works. The site selected is in a part of the City anticipated to industrially develop, due to the proximity of the proposed freight terminal railroad yards.

It is estimated that in 1950—80,000,000 gallons of sewage will be brought by the collecting sewers to this site. The effluent will be discharged into the river below tidal influence upon the river at Torresdale, and it is considered that the more refined treatment of the sewage at the proposed northeast and southwest treatment works will maintain the water of the Delaware River in a fit condition to receive and as-



Reinsch Screen in operation, Dresden, Germany.

similate without any offence to sight or smell the sewage from the southeast works if it is freed from all appreciable sized suspended matter.

The methods of treatment, therefore, proposed at this site will consist of coarse screens, grit chambers and fine screens with disposal of the screenings by incineration and of the effluent by diffusion in the channel of the Delaware River through submerged outfalls.

It is anticipated that the increase in population, the growth of industry, the extension of the sewer system and the increasing standards of hygienic cleanliness of the future will require more refined treatment of the sewage at the northeast and southwest works than the removal of the settleable solids.

This would consist in converting the decomposable organic matters in solution in the effluents of the tanks into more stable forms so as to maintain or even raise the ratio between the demands upon the oxygen of the river and its rate of replenishment.

Intermittent Sand Filtration

Based upon the investigations made by Frankland of the principles involved in the purification of sewage by application to farm land, the Massachusetts State Board of Health in 1887 began experiments upon the purification of sewage by filtering it through beds of sand which are naturally found in New England. It found that sewage could be intermittently applied to sand beds at a net rate of from 20,000 to 60,000 gallons per acre per diem and a clear, well-oxidized effluent obtained.

The natural glacial sand deposits of New England made this the most economical method of sewage treatment for those States, and "thus doubtless tended to instill into the minds of sanitarians the belief that it was desirable and perhaps necessary to purify sewage very thoroughly in all

cases where treatment was required before discharging it into running water."

For communities where such natural sand deposits exist or for small installations where sand beds can be artificially constructed such treatment may be desirable, but for the large quantities of sewage produced by the City of Philadelphia the expense of constructing the enormous areas of artificial sand beds would be unwarranted, for the degree of purification of the sewage by this method is unnecessarily high and the same results can be ultimately accomplished by the artificial treatment to a less degree at a great reduction in cost and utilizing the natural oxidizing power of the river.

Contact Beds

Historically, the next process for the oxidation of sewage was experimentally devised in 1892 by Dubden, at London, and is called the contact bed. It consists of watertight compartments containing a medium such as broken stone, slag, cinders, etc., to a depth of 4 or 5 feet. Sewage at least freed from its grosser suspended matter is introduced, filling the pores or interstices of the medium held in contact with it (hence the name of the process), then withdrawn and the bed allowed to rest and aerate. The biological action in a contact bed is very complex and the resulting effluent of properly operating beds should be fairly stable, showing that the putrescent organic matters have been oxidized. They can handle sewage at an approximate rate of 500,000 gallons per acre per diem. The adherence of sewage matters to the surface of the medium and the disintegration of the latter cause contact beds to lose capacity, so that in large installations some beds are always out of service having their medium washed.

Manchester, England, has the largest installation of contact beds, amounting to about 100 acres. These are found to

be expensive to operate and fail to produce an effluent equal to the requirements of the Rivers Board. The consensus of opinion among experts seems to be that contact beds for a large installation are not as efficient as percolating filters.

Percolating Filters

The most modern and intensive method for the oxidation of sewage is the percolating filter which consists of a bed of media such as broken stone, clinker or slag, supported upon a sloping floor with underdrains and enclosed by walls not necessarily water tight. The clarified sewage is applied to the surface of the medium by means of traveling distributors or fixed nozzles. This affords an opportunity for the sewage to absorb oxygen from the air and in this oxygenated condition it percolates over the surfaces of the stones upon which there develops a jelly-like film containing beneficent bacteria which effect the oxidation of the organic sewage matters, the carbon being converted into carbon-dioxide and the nitrogen into nitrate.

Part of the finely divided suspended matter and the colloids pass through the bed and part remain attached to the medium. This same condition is the cause of clogging in contact beds but in properly operated percolating filters the beds automatically unload the accumulated solids usually at the beginning of warm weather. There are many installations of percolating filters which after several years of service are in as clean a condition as shortly after being placed in service, due to this automatic unloading of the accumulated solids.

The effluent of a percolating filter does not differ noticeably in appearance from the applied sewage and during the time it is unloading, the former is much more turbid, but the solids which pass through the bed have been subjected to the oxidizing influences and are changed in character. When such effluent is discharged into a small stream

or body of water, not having velocity sufficient to maintain the settleable solids in suspension, it is necessary first to pass it through a settling basin having about two hours retention. But when the effluent of a percolating filter is discharged into a stream with a velocity sufficient to maintain the solids in suspension, this expense may be eliminated as the ultimate oxidation will be accomplished in the river water.

The possible objection to large installations of percolating filters is the danger of nuisance from spraying the sewage over the beds. This has been noticed at plants using septic tanks for preliminary treatment. But when the sewage is collected by a properly designed, constructed and maintained sewer system, clarified in two-story tanks so as to maintain its freshness, the danger from nuisance is reduced to a minimum.

In comparing the efficiency of the two most extensive methods of sewage oxidation, the Royal Commission of England on sewage disposal states in its fifth report:

> Taking into account the gradual loss of capacity of contact beds, a cubic yard of material arranged in the form of a percolating filter will generally treat satisfactorily nearly twice as much tank liquor as a cubic yard of material in a contact bed.
>
> Percolating filters are better adapted to variation of flow than contact beds. The effluents from percolating filters are usually much better aerated than the effluent from contact beds and, apart from suspended solids, are of a more uniform character. On emptying a contact bed, the first flush is usually much more impure than the average effluent from the bed.
>
> The risk of nuisance from smell is greater from percolating filters than with contact beds.

The last statement is based on experience with works not

using two-story tanks for clarification of the applied sewage.

The rate of operation of percolating filters varies between one million and two and one-half millions gallons of clarified sewage per acre per diem which is from two to five times as high as is usual in contact beds.

It is not believed that it will be necessary to oxidize the sewage of Philadelphia when collected at the treatment works for several years in the future, but the treatment works should be so designed as to include oxidation when it becomes necessary. With present knowledge, the percolating filters provide the most efficient method and it has, therefore, been decided to so locate the clarification tanks that their effluent can be applied to percolating filters in the future. Advances in the art of sewage treatment may develop improvements whereby higher rates of filtration may be used and also less head required. Much interest is aroused in the investigations now being carried on in England to obtain a clarified and oxidized effluent in tanks by means of air and "activated" sludge.

When oxidation is resorted to in Philadelphia, it will be required earliest at the Northeast Works as an additional safeguard to the water of the Delaware River used at the Torresdale Water filters.

SLUDGE

In sewage treatment, the material collected on the screens and the deposit in the bottom of sedimentation tanks is called sludge. As removed from tanks it is a dark, slimy mass, containing about 90 per cent. moisture, and its consistency is such that it cannot be shoveled but can be readily pumped.

To grasp the magnitude of the problem of handling the sludge produced by large cities, it is but necessary to state the quantities produced by some of the great cities of the

world. London, with a population of 6,000,000 tributary to the works, produces by chemical precipitation 2,597,000 tons of wet sludge of 92 per cent. moisture per annum. The district of Birmingham, England, with a population of 950,000, treats and disposes of 427,000 tons of wet sludge 94½ per cent. moisture per annum. The Metropolitan Sewerage Commission of New York, in its report, states that 266,000 tons of solids are annually discharged into New York Harbor and will require collection and treatment in the near future. This amount of solids as intercepted from the sewage if, in the form of 90 per cent. sludge, would be equivalent to 2,700,000 tons per annum from a population of 5,780,000.

Experience with sewage works indicates that upon an average 1,000 persons produce 45 tons of dry solid matter per annum. If this were deposited in tanks as sludge containing 90 per cent. moisture, it would make 524 cubic yards, but, if the sludge contained 95 per cent. moisture, its volume would be 1,060 cubic yards, or about double the former amount. In other words, every ton of dry solid matter contained in sludge 90 per cent. moisture which is removed requires 9 tons of water to be conveyed with it, and if the sludge contains 95 per cent. moisture, it requires 19 tons of water to be handled.

One of the most important considerations, therefore, in handling sludge is the percentage moisture which it contains, as this is a controlling factor in its bulk, as shown in the accompanying diagram. It is highly desirable to obtain sludge with as low a moisture content as possible.

Of the dry residue in the sludge, approximately one-half is organic and one-half mineral. A large part of the organic matter in freshly deposited sludge is highly putrescent and if improperly handled produces offensive odors. It is, therefore, also of importance that such processes of sludge treatment shall be used that reduce this offensive-

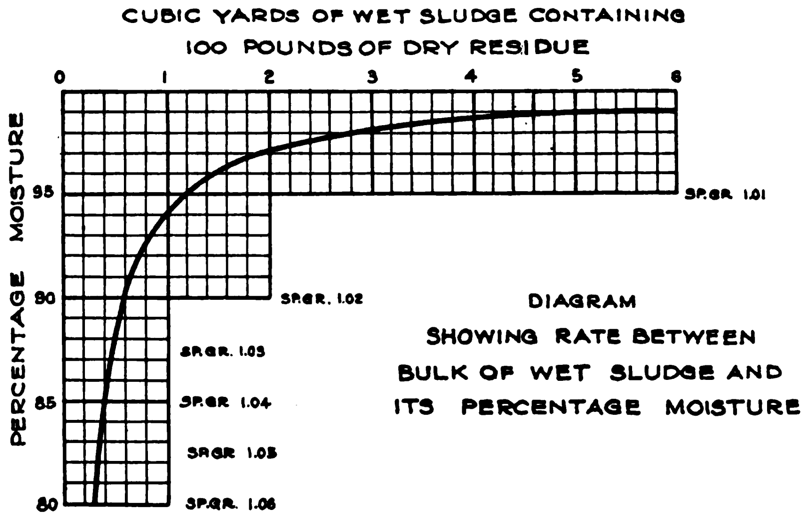


DIAGRAM
SHOWING RATE BETWEEN
BULK OF WET SLUDGE AND
ITS PERCENTAGE MOISTURE

CITY OF PHILADELPHIA
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
SEWAGE DISPOSAL DIVISION

ness by the destruction of the easily decomposed organic matter.

The final disposal of sludge is accomplished by (a) discharge of wet sludge in the sea; (b) depositing wet sludge on land; (c) the use of partially dried sludge for filling in low waste lands; and (d) where circumstances warrant the use of sludge as a fertilizer, fertilizer base or as fuel.

The problem of handling sewage sludge consists in disposing promptly and economically of the watery mass which contains offensive, decomposable matter without menace to the public health or the production of foul odors or other nuisances.

Discharge of Wet Sludge in the Sea

Large cities located near the ocean dispose of the wet sludge most economically by carrying it to sea in specially constructed tank steamers. The sludge is pumped from the sedimentation tanks to reservoirs on the wharf from which the steamers are filled by gravity. When the boat reaches the dumping ground in the open sea the outlet valves are opened and the sludge diffused in the sea water as the boat moves along.

This method of sludge disposal is used at London, England, where the sewage is collected by sewers to two works located on the banks of the Thames about 12 miles below London Bridge. Chemicals are added to the sewage to form a flocculent precipitate and free it from most of its suspended matter. The sludge thus produced after settlement contains about 92 per cent. moisture and is carried by 6 tank steamers 55 miles to Black Deep in the open sea, which is 20 miles below Southend. On an average 8,300 tons of sludge are thus disposed of every weekday at a cost of about 9 cents per ton (including interest and sinking fund charges).

At Manchester, England, the sludge from the septic

tanks is similarly carried by a tank steamer to the open sea beyond Mersey Bar. During the last fiscal year, 215,082 tons of wet sludge were dumped at sea at a cost of $32,000, or about 15 cents per ton.

Among other large cities disposing of their wet sludge in this way may be mentioned Glasgow, Scotland; Salford, England; and Dublin, Ireland. The Metropolitan Sewerage Commision of New York recommended this method of sludge disposal for that city as it appears to be the most economical, due to proximity to the ocean.

Depositing Wet Sludge on Land

For cities situated inland such method of disposal is impracticable on account of the transportation charges, and they are confronted with the problem of reducing the bulk of the sludge by removing the water, either by drainage and evaporation on drying beds or by mechanical processes, such as presses and centrifuges and of handling it so as to minimize offence.

The type of sedimentation tank adopted, the use of chemical precipitation or the opportunity afforded for sludge digestion has a marked effect upon the volume of sludge produced on account of the moisture content. Generally speaking, it may be said that chemical precipitation will produce between 20 and 25 cubic yards of wet sludge containing about 92 per cent. moisture from each million gallons of sewage treated; plain sedimentation from 4 to 7 cubic yards between 87 and 93 per cent. moisture; septic tanks from 1.5 to 3.0 cubic yards between 80 and 90 per cent. moisture; and Emscher or Imhoff tanks from 1 to 2.5 cubic yards between 75 and 85 per cent. moisture.

Lagooning

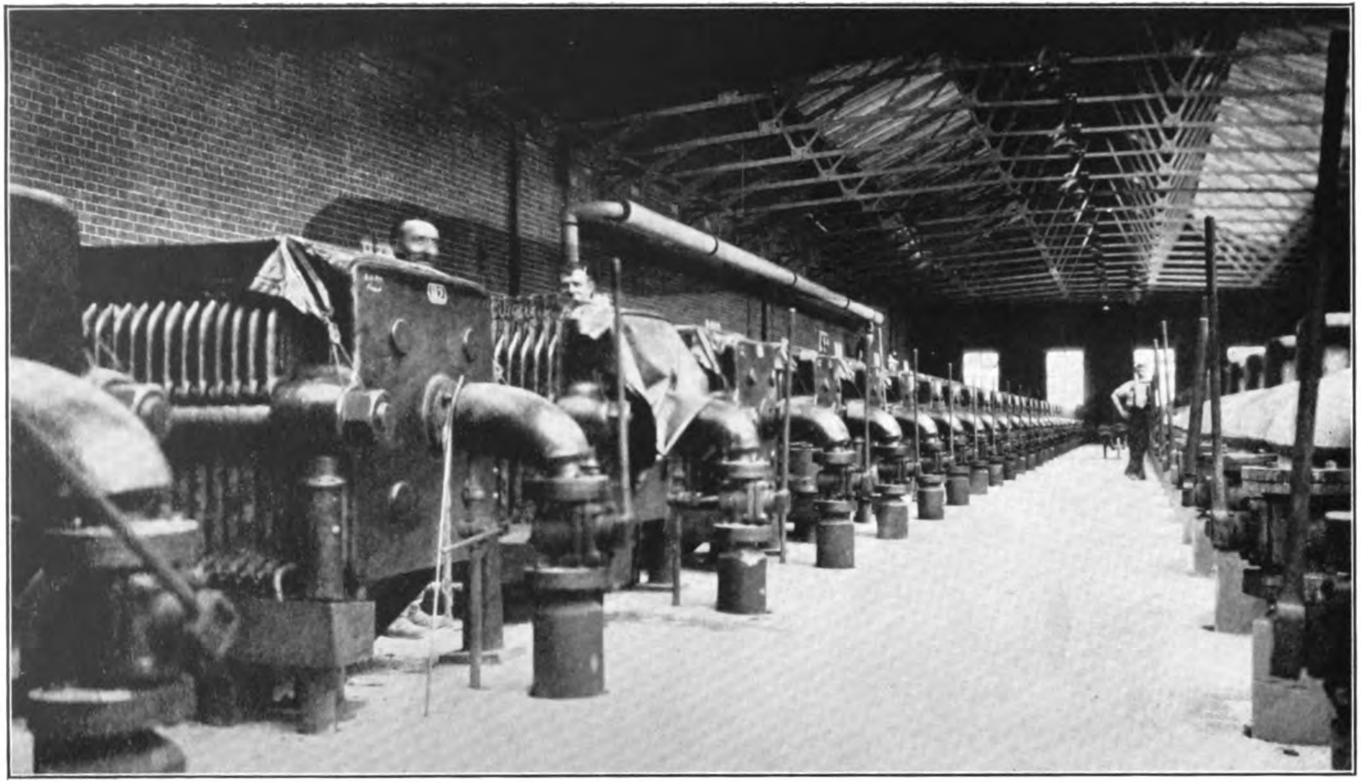
The disposal of wet sludge without prior dewatering may be accomplished by its application to land in several

ways. The earliest method used was called lagooning, in which case earth embankments were built enclosing an area of suitable land and the wet sludge run in to a depth of as great as 10 feet. The clogging of the soil preventing free drainage of the moisture, the scum formation upon the surface retarding evaporation, and the frequent great depth of the sludge all tend to prevent it from drying. As an example, there are sludge lagoons at Birmingham, in which the sludge deposited many years ago is practically in the same condition as shortly after being placed except that a heavy crust has formed upon the surface. This method is rapidly being abandoned.

Trenching

To overcome these objections and to dispose of the sludge more quickly, it was run upon the surface of farm land to form a shallow layer which would dry in a reasonable time and could then be plowed in and the field cultivated. But the gross nuisance created by the exposure of such large areas of foul smelling sludge led to the adoption of what is called trenching. As practiced at Birmingham, England, the trenches were dug about 3 feet wide and 18 inches below the surface of the soil, the excavated earth forming banks between the trenches, so that they could be filled to a depth of from 24 to 30 inches with wet sludge, after which the tops of the earth banks were thrown over the sludge to prevent nuisance from smell or flies. The porous earth absorbs the moisture and later the land is plowed across the trenches and placed under cultivation. This process can be repeated at intervals of from 18 months to 2 years.

The cost of trenching at Birmingham amounted to about 8 cents per ton of wet sludge. This is exclusive of the cost of sludging tanks, but includes interest on capital outlay at 5 per cent. and rent of land. This method is not



Sludge Presses for Grease Recovery, Bradford, England.

being used in new plants and is being abandoned in old plants on account of the area required, the interference which is caused in times of heavy storms, the increased difficulty of operating caused by winter weather and the general cumbersomeness of the method.

Mechanical Processes for Dewatering Sludge

Pressing

Among the early mechanical methods of reducing the bulk of the wet sludge by dewatering was pressing in machines (those used at Bradford, England, being shown in accompanying illustrations) which consist of a number of cast iron plates generally 9 square feet in area, with corrugated faces and surrounded by a machined rim so that when placed together they form water tight cells about 2 inches thick. A central pipe about 6 inches in diameter extends through the middle. Over each plate a canvas cloth is placed and sludge forced into the press and subjected to a pressure of from 60 to 75 pounds per square inch. This squeezes the water out and the resultant cake contains between 50 and 65 per cent. moisture and is about one-fifth the bulk of the original wet sludge.

It is necessary to add to the sludge before pressing from ½ to 1 per cent. of lime, the fine particles of which facilitate the passage of water, the dissolved lime agglomerating the solids of the sludge. The cost of pressing largely depends on the amount of lime added, the kind of sludge pressed and the magnitude of the works; in large cities the average cost is 10 cents per ton of wet sludge.

At Worcester, Mass., about 18,000,000 gallons of sewage a day are received at the chemical precipitation works. There are added 55.5 pounds of lime to each 1,000 gallons of sludge, which contains on an average about 90 per cent. moisture when pumped from the tanks. The presses reduce

the moisture to about 70 per cent. and 0.167 tons of sludge cake are obtained from each cubic yard of the wet sludge. The pressed cake is hauled in electrically propelled cars about a mile and disposed of for filling low waste land.

Centrifuges

Another mechanical method of dewatering sludge is by means of centrifuges which occupy less space than presses and do not require the addition of lime to the sludge. Such machines are continuous in action and the work of extracting the moisture consists of two distinct and constantly repeated periods. During the first period the wet sludge is introduced into the machine and by the action of centrifugal force the moisture content reduced. During the second period the sludge thus partly dried is automatically ejected. The final product contains about 60 per cent. moisture and occupies about one-eighth the volume of the wet sludge.

The largest installation of these machines is in Frankfurt-on-Main, Germany, where the sewage of 400,000 people is subjected to plain sedimentation, and about 310 tons of wet sludge 90 per cent. moisture obtained per diem. The sludge is pumped to overhead reservoirs and kept agitated by revolving paddles. From thence it is fed to 8 centrifugal driers capable of handling 325 cubic yards of wet sludge a day of 10 hours. After drying it is carried by a conveyor through a tunnel heated by the exhaust gases from the power station and, as a 20 per cent. moisture mass resembling soft coal of a gray color, is mixed with garbage and both disposed of by destructors, the steam being used for generating electricity for power and lighting.

Digestion of Sludge

In the methods of sludge handling above described efforts were directed toward preventing the dissemination

of the foul odors from the wet mass. Within recent years much thought has been given to devise processes of treatment by the digestion of the putrescent matters to produce an inoffensive sludge both as withdrawn from the tanks and during drying.

Separate Sludge Tanks

One of the methods to accomplish this purpose is to remove the freshly deposited sludge from the sewage sedimentation tanks at intervas and place it in separate tanks. Usually a scum forms upon the surface beneath which more or less active fermentation and decomposition develops. New sludge is added and digested sludge withdrawn from time to time and placed upon underdrained sand or cinder beds for drying. On account of the digestion of the sludge it dries more rapidly and is much less offensive than when fresh.

This method is now in use at Baltimore, Md., where the sewage is freed of its settleable solids in large tanks. The accumulated sludge is removed at intervals by centrifugal pumps and discharged into adjacent concrete tanks where considerable digestion occurs, as indicated by the continuous ebullition of gas which is inoffensive. At first, the sludge was withdrawn from the digestion tanks and dried upon underdrained sand beds. It could be removed in a much shorter time than undigested sludge, and but little offense was created. At the present time, part of the wet sludge from the digestion tanks is being sold to farmers for use on truck farms. The same method of separate sludge digestion is in use at Birmingham, England, the dried material being used to fill in a deep ravine between railway fills.

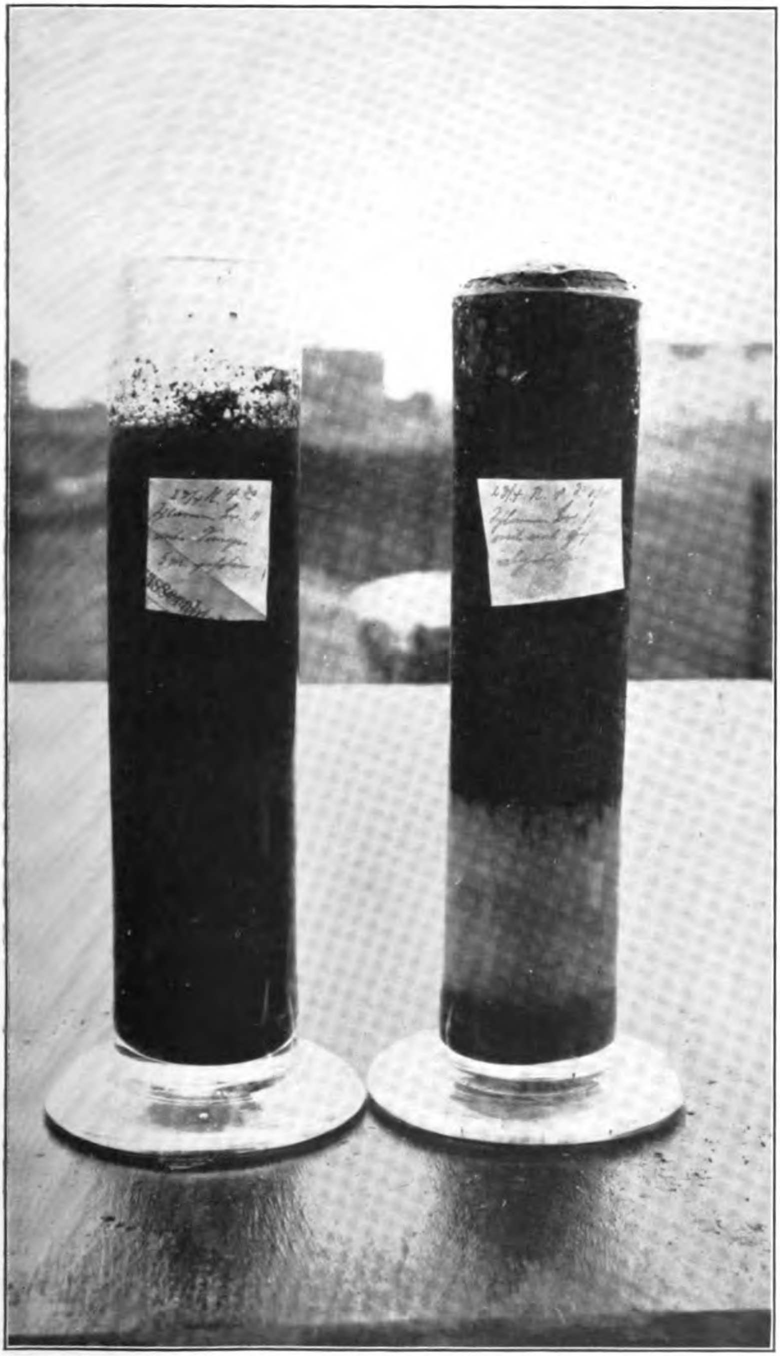
Two story Tanks

The Septic, Travis and Imhoff tanks have been described as devices for settling the sewage. Considering the sludge

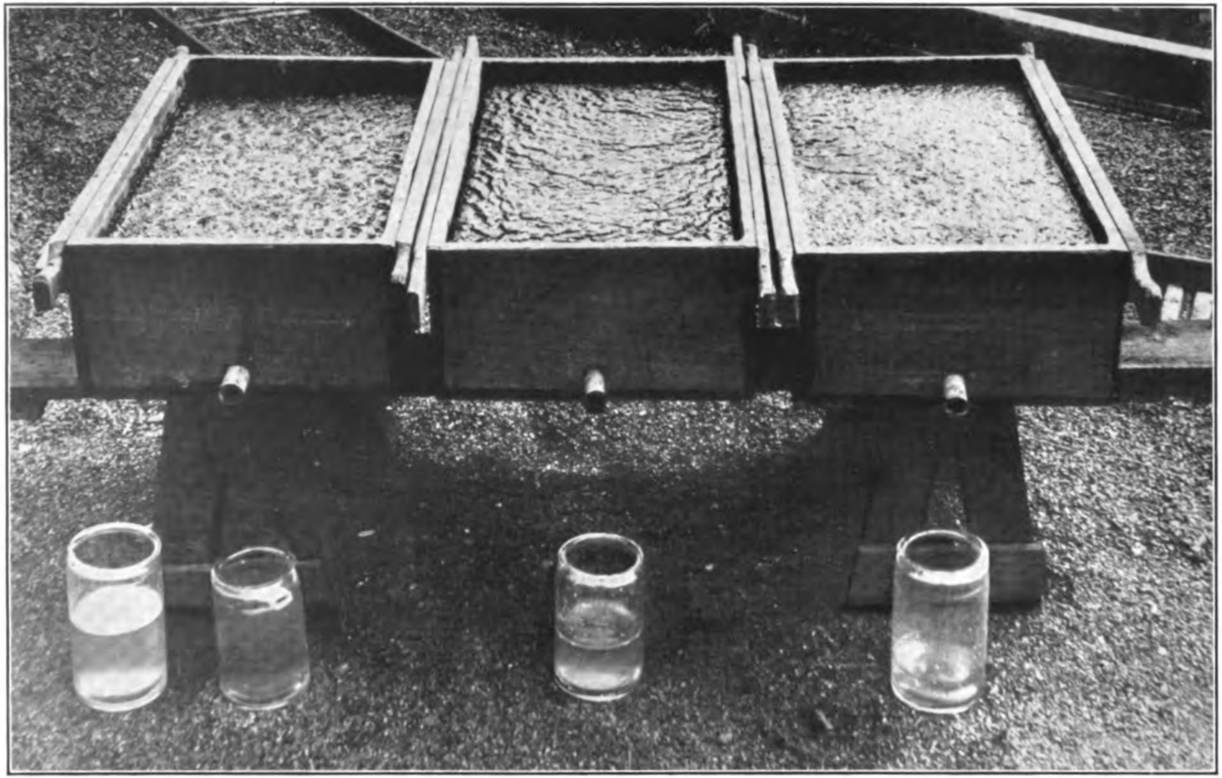
produced by each, it may be stated that the digestion occurring in the septic tanks reduces the water content of the sludge and somewhat aids in its drainability and reduces its offensiveness; the sludge storage capacity of the Travis tank does not appear to be large enough to provide time for the digestion of the organic matters and the sludge as withdrawn is malodorous.

Emscher or Imhoff Tanks

When an Emscher tank is first put in operation it is entirely filled with sewage; as there is no flow through the sludge compartment, decomposition develops therein and the putrescent matters in solution and as colloids are largely destroyed. The sludge deposited in the lower compartment is, therefore, covered by a water having characteristics different from those of fresh sewage, and it is the opinion of some that this is the cause of the inoffensive sludge digestion, the gases evolved under these conditions being principally methane and carbon-dioxide. These gases while in the sludge, are under a hydrostatic pressure due to the depth of the tank, and when the sludge is withdrawn upon the drying bed the bubbles expand, lightening the mass and aiding in a separation of the water, which flows to the bottom and is carried away by the drains of the drying bed. This is shown in the accompanying illustration. Both cylinders were filled to the same depth with sludge drawn simultaneously from a mature Emscher tank. The sludge with which the left-hand cylinder was filled had been pumped so as to expand and liberate the entrained gas bubbles. The sludge with which the right-hand cylinder was filled was drawn in a normal manner and contained the gas bubbles under pressure. It will be noted that the water stands on top of the sludge in the left-hand cylinder, while in the right-hand cylinder the expansion of the gas bubbles has increased the volume of the sludge, causing it



Effects of Expansion of Gas Bubbles in Emscher Sludge shown in Right-hand Cylinder.



Drain water from Sludges obtained from Sedimentation, Septic and Emscher Tanks.

to rise even above the top of the glass, and in the bottom of the cylinder is seen the water which, had the sludge been placed on a sand bed, would have drained away. The digestion of the sludge also reduces its sticky, tenacious nature and facilitates its parting with the water. As is shown in the experiment illustrated in the accompanying half-tone, three wooden boxes of identical dimensions containing sand in the bottom and a drain pipe were filled with three different kinds of sludge. The right-hand box contained sludge resulting from plain sedimentation; the middle box contained sludge withdrawn from a septic tank; the left-hand box contained sludge withdrawn from a mature Emscher tank. The glasses beneath each drain pipe show the amount of water which drained from each sludge in the same time. It will be noted how the level of the Emscher sludge is much lower than the others, due to its shrinking in volume and the much larger quantity of drain water obtained from it.

In normal weather sludge from a matured Emscher tank will dry on sand beds in from 3 to 5 days to a consistency fit to remove, while sludge from septic tanks requires at least two weeks' time, and sludge from plain sedimentation tanks will require about 8 weeks in summer, and at least twice that length of time in winter, to be dry and firm enough to handle.

Dried Emscher sludge is suitable for filling lowland or use in agriculture, particularly in lightening heavy soils, as it is very spongy in texture, due to the entrained gas. But experience has demonstrated that the use of air-dried sludge from any source will not give results comparable with those obtained from the use of artificial fertilizers.

The rapid drying of sludge digested in Emscher tanks allows of very much smaller sand beds than for other kinds of sludge; in fact, it is usual to provide only 1 sq. ft. of bed for each three persons tributary to the tank.

The first full-sized installation of Emscher tanks was at Rechlinghausen, Germany, in 1907, for a population of 30,000. The marked improvement in quality of tank effluent and sludge obtained over all previous types of sewage tanks led to the adoption of the principle at first in Germany, and later in this country. The two largest installations are at Bochum, built in 1908 for 145,000 people, and Essen Nord, built in 1911 for a population of 180,000.

In the Pennypack Creek sewage treatment works, Emscher tanks are in use as described in the appendix to this report. They are also being operated successfully at Atlanta, Ga., and in Batavia, N. Y.; they are also being installed at Baltimore to provide increased capacity instead of enlarging the present system of sedimentation and separate sludge digestion.

In the accompanying diagram is shown graphically the relative volumes of wet sludge and of dry residue obtained from 1,000,000 gallons of sewage by different methods of sewage treatment and sludge drying. The outside cubes indicate the total volume of the sludge and the shaded cube shown in the lower left-hand corner of each larger cube represents the volume of dry residue. The difference in volume between the two, therefore, represents the volume of water in the sludge.

The upper row of cubes represents sludge as deposited in the tank. Considering sludge deposited from plain sedimentation as normal, the increase in volume of wet sludge obtained by chemical precipitation is very evident. The larger amount of dry residue shown by the shaded cube for chemical precipitation is due to the presence of the chemical coagulant and to the fact that more suspended matter is removed by this process than by sedimentation unaided by chemicals. The smaller size of the cubes representing sludge from septic tanks and Emscher tanks is due to their lower moisture content, and the smaller amount of

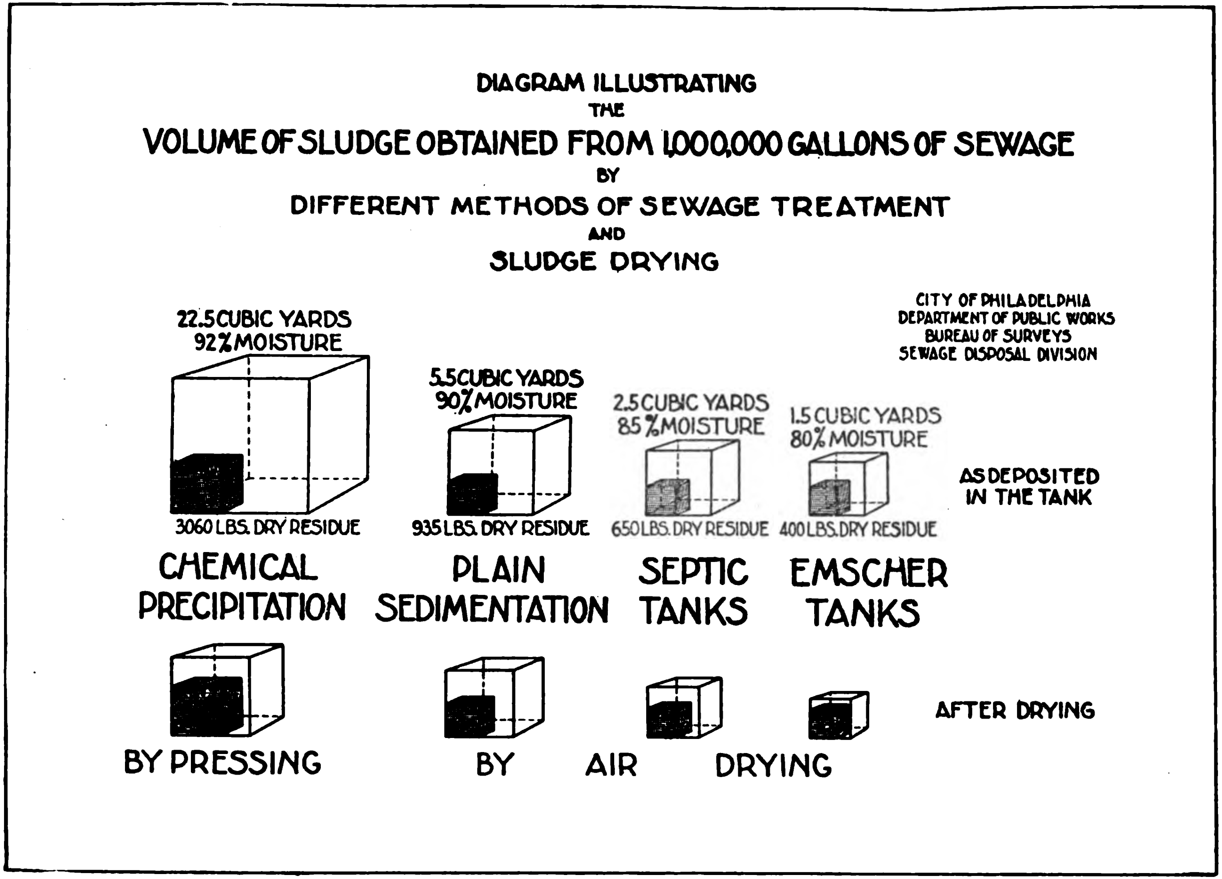


DIAGRAM ILLUSTRATING
THE
VOLUME OF SLUDGE OBTAINED FROM 1,000,000 GALLONS OF SEWAGE
BY
DIFFERENT METHODS OF SEWAGE TREATMENT
AND
SLUDGE DRYING
CITY OF PHILADELPHIA
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
SEWAGE DISPOSAL DIVISION
22.5 CUBIC YARDS
92% MOISTURE
3060 LBS. DRY RESIDUE
CHEMICAL PRECIPITATION
5.5 CUBIC YARDS
90% MOISTURE
935 LBS. DRY RESIDUE
PLAIN SEDIMENTATION
2.5 CUBIC YARDS
85% MOISTURE
650 LBS. DRY RESIDUE
SEPTIC TANKS
1.5 CUBIC YARDS
80% MOISTURE
400 LBS. DRY RESIDUE
EMSCHER TANKS
AS DEPOSITED IN THE TANK
BY PRESSING
BY AIR DRYING
AFTER DRYING

dry residue shown indicates the results of the digestion of the organic matter due to the retention of the sludge in the tank.

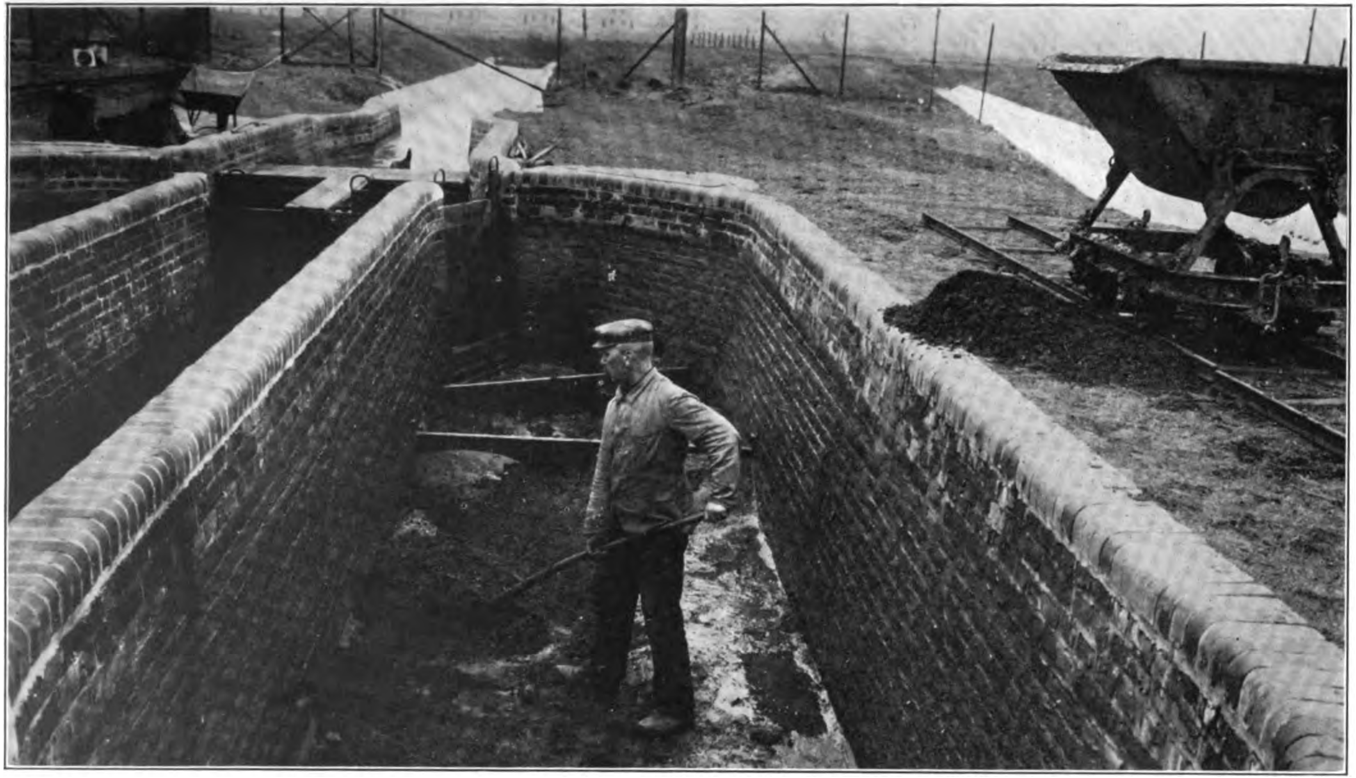
In the lower row of cubes is shown the relative volumes of the various kinds of sludge after partial dewatering. It will be noted in each case that the shaded cube representing dry residue is of the same size as the corresponding cube in the wet sludge as deposited, the reduced volume of the dried sludge being entirely due to the extraction of moisture.

When it is borne in mind that the volumes of these figures are in proportion to the cubes of their edge, the great difference between the volume of wet sludge deposited by chemical precipitation and of air-dried Emscher sludge is evident.

The Recovery of Ingredients from Sludge which may have Value

Sludge contains ammonia, phosphoric acid, potash, grease and carbon. Generally speaking, these ingredients are more costly to recover than they are worth. It has been estimated that the manurial value in the excreta of one person in a year is $2.62, but in the dilute sewage of America this would be contained in about 36,000 gallons of water. If this material is deposited as sludge of 90 per cent. moisture it would weigh about 1,720 pounds per cubic yard, and each cubic yard would contain only about 80 pounds of organic matter, of which only a part has any monetary value.

The problem of recovering the valuable ingredients in sewage sludge, therefore, involves the use of economical and efficient processes for drying or pressing to reduce the bulk for transportation. In order to recover the grease in sewage with present methods, it is necessary to have the sludge in a very dry condition.



Grit Chamber, Essen, Germany.

Dr. MacLean Wilson, Chief Inspector of the West Riding of Yorkshire Rivers Board, who has supervision of the disposal of sewage from 3,000,000 persons located in the center of England, in reporting upon the utilization of sludge, takes a hopeful view of utilizing that part of the valuable ingredients of sewage which can be extracted in the form of sludge. An early solution of this problem lies, in his opinion, in the fact that there are many capable experimenters at work in the effort to prevent the waste at a cost which permits the sludge to be prepared and transported in a condition profitable to agriculturists.

Mr. H. W. Clark, Chemist of the Massachusetts State Board of Health, in charge of the Lawrence experiment station, as a result of his study, expresses the opinion that sludge has some value and as the processes of drying, pressing, and fat separation are improved and as nitrogen advances in price, it seems inevitable that sewage sludge will become of greater agricultural value than it is at present, especially as the basis of fertilizers enriches by the addition of potash, phosphates, etc.

The Metropolitan Sewerage Commission of New York City, after an exhaustive study of the question of utilization, does not encourage the belief that any great profit can be derived, except in cases where the nitrogen or fats are abnormally high. It states that under other conditions, past attempts to secure anything more than a nominal revenue have, as a rule, resulted in failure. The crux of the problem is the separation of the water and the concentration of the valuable ingredients. This is necessarily costly whether done mechanically or by the direct action of heat.

For many years the so-called Globe Fertilizer has been manufactured from sewage sludge at Glasgow where the sewage is precipitated with lime and ferrous sulphate. Most of the sludge is sent to sea, but part is pressed and dried by heat, passed through a pug mill and sold as fertilizer.

The Royal Commission of England states that it is more economical to sell pressed cake than to make the fertilizer and less is being made each year.

Bradford is the center of the wool industry in England and large quantities of wool washing water are added to the sewers amounting to one-tenth of the total amount of sewage, which, therefore, contains abnormally large amounts of grease. The sludge is first treated with sulphuric acid and then heated to 212 degrees Fahr. It is then pressed hot and grease mostly obtained in the hot press liquor which is then boiled with chemicals and the resultant grease sold at from $35 to $50.50 per ton. Excluding certain fixed charges, it is claimed that the recovery of the grease is done at a profit.

Enlargement in the capacity of the Birmingham Sewage Works for handling sludge is contemplated by the use of the Dickson process as it was worked at the Dublin Sewage Outfall Works. "In this method of handling sludge about 0.5 per cent. of yeast is added to the sludge as removed from the tanks and the mixture pumped through a heater which consists in a number of pipes placed in the path of the hot-air from the furnace to fermenting troughs in the bottom of which are hot-air ducts to keep the fermenting sludge at about 90 degrees Fahr. In 24 hours, as a result of the fermentation, there is a distinct separation of water, the sludge at a density of about 83 per cent. occupying the surface while the water can be readily drained away beneath. A compound of phosphates and potash in about equal proportions by weight of sludge and compound based on dry solid matter is then added and the mixture containing about 73 per cent. water is then pumped to the dryer, which consists of a cylindrical vertical casing containing a series of arms and platforms. Air at a temperature of about 450 degrees Fahr. is blown into the dryer at the bottom and passes out the top. The dried mixture falls

Emscher Tank Installation at Essen Nord, Germany.

Sludge Drying Beds at Essen Nord, Germany.

into a disintegrator which beats it up into a powder, which would be used as fertilizer."

Experiments made in the sewage testing station operated by the Bureau of Surveys in 1909 and 1910 in burning several kinds of dried sludge and in mixing wet sludge and fine coal which was burnt when dried confirm the accepted conclusion that while sludge when dried has a certain value as fuel, which is influenced by the source and amount of moisture which it contains, it is not practicable to recover completely this calorific value in actual amounts of water evaporated by the burning of the sludge.

When refuse disposal plants and sewage treatment works are located in close proximity to each other, an opportunity is offered for the advantageous disposal of sewage sludge by burning it with refuse. This is now being accomplished at Frankfurt-on-Main, Germany, already referred to.

The manipulation of sludge so as to utilize the calorfic value has also been the subject of experimentation in Germany, followed by the installation of full-sized plants. Two notable plants are those at Ober-Schöneweide, and at Potsdam, both near Berlin.

In the former, layers of sludge of 60 per cent. moisture and culm or dust of brown coal are run into a gas producer, and utilized to run a 60 horse-power gas motor generating electric energy, used for power and lighting about the plant and adjacent street lighting. The report of operation, based upon the possible sale of all power at 2½ cents per kilowatt hour, for the plant in question, shows a profit of 50 per cent. on the net cost of production, exclusive of interest on invested capital. The fact of the construction of typical four-story apartments across the street from the plant, after the installation, argues well for the maintenance of sanitary conditions.

In the other case, that of Potsdam, the brown coal is added in the proportion of 1 part coal to 8 of sludge in the

sedimentation process, also about 150 grams of sulphate of iron per cubic meter of sewage. These contribute to the separation of the solids from the liquids. The sludge thus produced is pressed into briquettes of 60 per cent. moisture having a heat value of 1,500 units. The briquettes form the only fuel in a city electric plant in an adjoining building. It is said that the cost of briquetting about equals the value of the electric energy, the benefit being the innocuous disposal of sludge without cost.

Experiments are to be made at Birmingham, England, to utilize the air-dried sludge by burning it in specially constructed furnaces in order to obtain heat for the separate digestion of about one-sixth of the wet sludge by the new yeast fermentation process previously mentioned.

Disposal

In order that the purification of the sewage shall be promptly accomplished by the natural processes in the river after the artificial treatment in the proposed works, it is necessary that the effluent of the treatment works shall be diffused with the river water. If the effluent were discharged at the bank of the river it would not readily mingle with the main currents, due to an inadequacy of diluting water. It is, therefore, proposed to discharge the effluent through conduits laid in the bed of the river terminating in the channel in multiple outlets. This will cause the discharge to occur in the deepest water, and when it can be assimilated by the great tidal flow.

The sludge at the northeast and southwest works after drying on the sand beds can be utilized for filling in the low lands adjacent to the works and the screenings at the local pumping station, and the southeast works can be incinerated to avoid any offence from handling material containing such a large proportion of organic matter in built-up parts of the City.

THE PLAN RECOMMENDED

FOR THE

COLLECTION, TREATMENT AND DISPOSAL

OF THE

SEWAGE OF THE CITY OF PHILADELPHIA

Preliminary Studies

Numerous projects for collecting and treating the sewage of the city were carefully studied; plans and profiles of collectors, designs of pumping stations and treatment works and estimates of cost of construction and annual charges prepared. By a process of elimination the more desirable projects were selected and given extensive study, and of these the following project was finally decided upon as the most economical and efficient plan.

Division of the City into Three Parts

The plan recommended is only general in character; details have only been developed sufficiently to determine the economical location of sewers, type of works and for the purpose of estimating costs. Each feature is sufficiently elastic that improvements in the art of sewage disposal may be incorporated in the works as they are constructed progressively.

In order to have a plan by which results can be obtained in the shortest possible time and to utilize such funds as

may be appropriated to the best advantage, it is recommended that the city be divided into three divisions:

1. The Northeast Division is that part of the city northeast of a line beginning on the Delaware River at Port Richmond and extending to and along the Wissahickon Creek.

2. The Southwest Division is that part of the city included in the watersheds of the Schuylkill River, the southwest side of Wissahickon Creek, the northeast side of Cobbs Creek, and that part of the Delaware River watershed having sewer outlets between Port Richmond and Market Street.

3. The Southeast Division is that part of the city included in the Delaware River watershed between Market Street and the Philadelphia Navy Yard.

The sewage of each of these divisions will be brought to a treatment works to be located within the division at a point where the effluent of the works can be discharged into the Delaware River.

The Northeast Division

Collection

A high level collector should be constructed along the south bank of Frankford Creek between county line (F on plan and profiles) and the vicinity of O and Luzerne Streets (G), to gather the sewage discharged into Frankford Creek, consisting at first principally of that from Germantown.

The upper reaches of Frankford Creek flow through park property and a higher degree of cleanliness is therefore desired than on the lower parts of the stream.

The collector is designed so that three-fourths of its ca-

The Wingohocking Sewer at Fifth and Annsbury Streets.

pacity is 200 per cent. of the average dry weather flow instead of 141 per cent. as in other parts of the city.

Another high level collector should have its upper terminus at Twenty-fourth and Westmoreland Streets (J), where it would divert the sewage collected by the separate systems from that part of Germantown on the northeast watershed of the Wissahickon Creek, which, according to the present sewer alignment, was intended to be discharged into the Gunners Run and Cohocksink main sewers.

This collector would carry the sewage along Westmoreland Street and Allegheny Avenue to Second Street, where the sewage from Gunners Run main sewer would be added by a short spur to that already collected and all carried in a northeasterly direction to the vicinity of N and Luzerne Streets (G), where it would join the Frankford Creek high level collector.

Another high level collector should have its upper terminus at Pratt and Leiper Streets (E), where it would collect sewage from the Wakeling Street sewer system and other sewers above its line, as the sewer flows in a southerly direction, passing under Frankford Creek in an inverted siphon, terminating in the vicinity of O and Luzerne Streets (G).

The three high level collectors will join in the vicinity of O and Luzerne Streets. Here will be located coarse screens, a grit chamber and an overflow to the creek for the excess rain water carried by the Frankford Creek high level collector.

After the large floating matter and grit have been removed the sewage will be carried by an inverted siphon consisting of three tubes 66, 78 and 90 inches in diameter to the site of the Northeast Treatment Works.

In order to lay the inverts of these tubes on a constantly descending grade and have the terminus at the works at an elevation such that they can be blown off at or near

high water, so that the ebbing tide will carry the contents away from the Torresdale intake, it will be necessary to raise the street grades of Wheat Sheaf Lane over a part of the line and it is also desirable to widen that street to a width of 70 feet.

It is estimated that these three sewers would collect in the year 1950 the sewage of 740,000 people, amounting to 130,000,000 gallons per day, and the siphon would discharge it at a sufficient elevation that it would flow through the treatment works without pumping.

The separate system of sewers should be installed upon the watershed of Pennypack Creek between Frankford Avenue and the county line, and an interceptor constructed along the creek from State Road (C) to county line (B).

Upon the drainage area tributary to the Delaware River between the mouth of Poquessing Creek and Princeton Street (D) in Tacony, shown in gray tint in the frontispiece, the separate system of sewers should be installed and also connections made between the storm water conduits and the collector, so as to intercept the first flush of the rainfall. This will prevent any local pollution from sewage, even during rain storms, of the Delaware River over three and one half miles of the shore adjacent to the intake of the Torresdale water filters. The sewage and first flush of rain water gathered from this area should be carried by the collectors to the present Pennypack Creek pumping station, which, with some enlargements, will lift it into the collector from the Pennypack Creek drainage area and the combined flow carried in a low level collector parallel to the Delaware, which will gather the sewage and first flush of rain water from sewers emptying into the Delaware River between Pennypack Creek and Orthodox Street and carry it to the Northeast Works where it will be pumped to an elevation required to carry the sewage through these works.

To collect the sewage discharged into Frankford Creek at too low an elevation to reach the Northeast Works by gravity, low level collectors should be constructed along each side of the creek (H-I) and their combined flow carried down Orthodox Street to the upper Delaware collector and thence to the Northeast Works.

It is estimated that these sewers would collect in the year 1950 the sewage of 224,000 people, amounting to 54,000,000 gallons per day.

The only remaining part of the Northeast Division is that between Somerset Street and the treatment works and southeast of the line of Gunners Run high level collector; this area is quite flat and the sewers low. It is therefore advisable to construct a low level collector a few squares back from the river, having its upper terminus at Richmond and Somerset Streets (L), to gather the sewage from the combined sewers northwest of it, and to install the separate system over the low area between the collector and the river bank for the collection of that sewage. This collector would deliver its contents to the same pumping station as that for the upper Delaware collector.

It is estimated that this sewer would collect in the year 1950 the sewage of 136,000 people, amounting to 24,000,000 gallons per day.

The complete collecting system above described will prevent the discharge of the crude sewage and first flush of rain water into Pennypack and Frankford Creeks and into the Delaware River between Port Richmond and the mouth of the Poquessing Creek, thus protecting the Delaware from pollution by crude sewage from Philadelphia within the tidal range of the intake of the Torresdale water filters and maintaining Frankford and Pennypack Creeks in a clean condition. It is estimated that it will concentrate at the Northeast Treatment Works in 1950 the sewage from 1,100,000 people, amounting to 208,000,000 gallons per day.

Treatment Works

The city should purchase at the earliest possible date before private development a tract of land south of Bridesburg, in the vicinity of Wheat Sheaf Lane and the Delaware River, sufficient for the proposed Northeast Treatment Works. The outer border of this tract should be parked and thus make the adjoining property attractive for development.

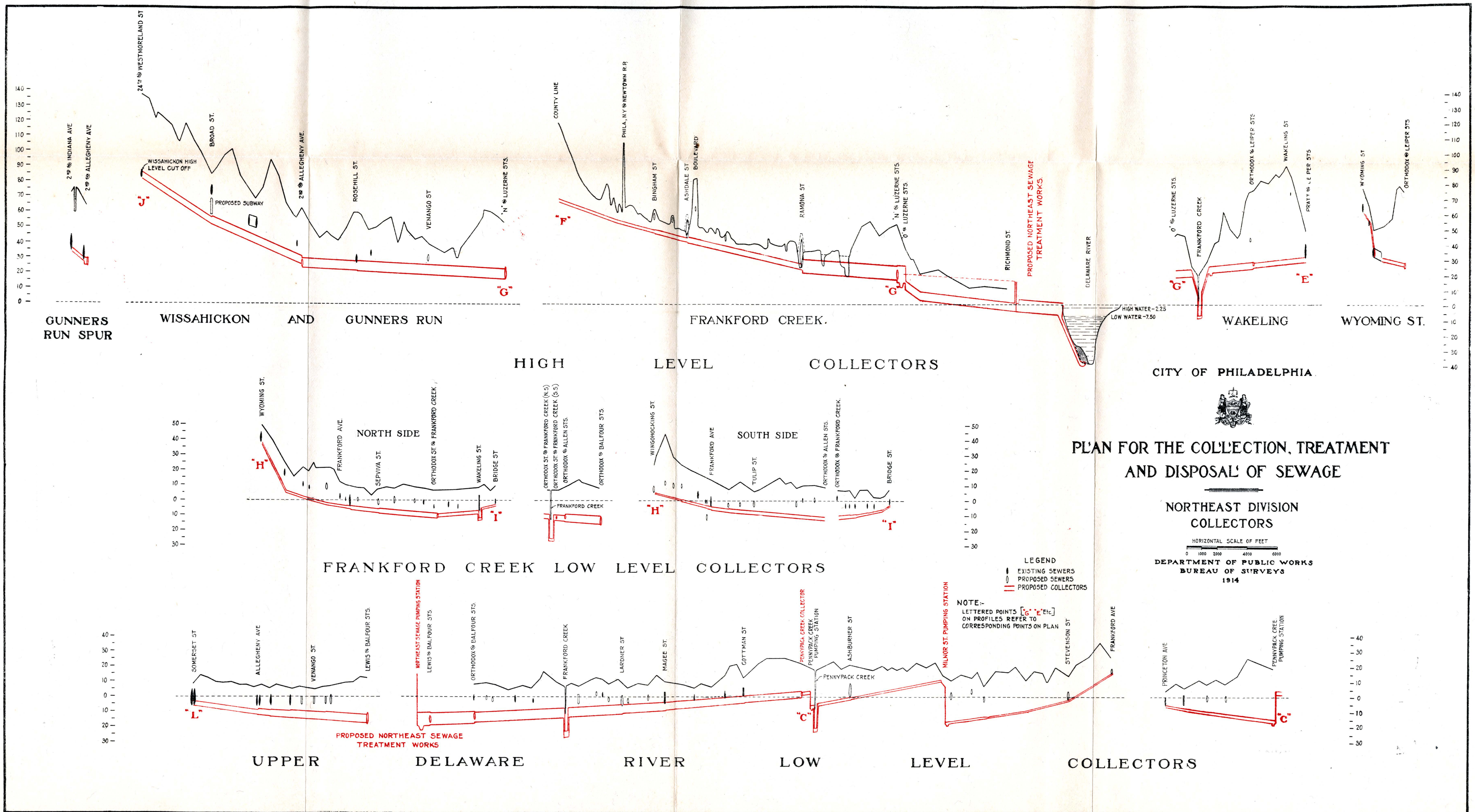
At this site the sewage collected by the upper Delaware low level collectors should be passed through coarse screens and grit chambers and pumped to the same elevation that the high level sewage will be delivered by the siphon and the combined flow passed through tanks for the sedimentation of the sewage and digestion of the resultant sludge. The most desirable tank for this purpose is that known as the Emscher tank described in this report under the subject of "Treatment of Sewage".

Adjacent to the tanks there should be constructed drying beds for the sludge withdrawn from the tanks after its thorough digestion.

A large part of the site of the Northeast Works is at a low elevation and the dry sludge will be suitable material for use as filling to bring the area up to grade, thus accomplishing the double purpose of disposing of sludge and filling in the low land.

Under present conditions the Delaware River is receiving the crude sewage from sewer outlets located in the northeast division of the City and the water of the river, after purification at the Torresdale water filters, affords a satisfactory supply.

When, in the future, the sewage is collected to the Northeast Treatment Works and a considerable part of the polluting material removed the river will be capable of receiving larger volumes of effluent than the present discharge of crude sewage.



GUNNERS RUN SPUR
WISSAHICKON AND GUNNERS RUN
FRANKFORD CREEK.
WAKELING
WYOMING ST.
HIGH LEVEL COLLECTORS
24TH & WESTMORELAND ST
WISSAHICKON HIGH LEVEL CUT OFF
PROPOSED SUBWAY
BROAD ST.
2ND & INDIANA AVE
2ND & ALLEGHENY AVE
2ND & ALLEGHENY AVE.
ROSEHILL ST.
VENANGO ST
"N" & LUZERNE STS.
COUNTY LINE
PHILA, N.Y. & NEWTOWN R.R.
BINGHAM ST.
ASHDALE ST.
BOULEVARD
RAMONA ST
"N" & LUZERNE STS.
"O" & LUZERNE STS.
RICHMOND ST.
PROPOSED NORTHEAST SEWAGE TREATMENT WORKS.
DELAWARE RIVER
HIGH WATER - 2.25
LOW WATER - 7.50
"O" & LUZERNE STS.
FRANKFORD CREEK
ORTHODOX & LEIPER STS.
WAKELING ST.
PRATT & LEIPER STS.
WYOMING ST.
ORTHODOX & LEIPER STS.
"J"
"G"
"F"
"E"
FRANKFORD CREEK LOW LEVEL COLLECTORS
NORTH SIDE
SOUTH SIDE
WYOMING ST.
FRANKFORD AVE.
SEPVIVA ST.
ORTHODOX ST. & FRANKFORD CREEK
WAKELING ST.
BRIDGE ST.
ORTHODOX ST. & FRANKFORD CREEK (N.S.)
ORTHODOX ST. & FRANKFORD CREEK (S.S.)
ORTHODOX & ALLEN STS.
ORTHODOX & BALFOUR STS.
FRANKFORD CREEK
WINGOHOCKING ST.
FRANKFORD AVE.
TULIP ST.
ORTHODOX & ALLEN STS.
ORTHODOX & FRANKFORD CREEK
BRIDGE ST.
"H"
"I"
UPPER DELAWARE RIVER LOW LEVEL COLLECTORS
SOMERSET ST.
ALLEGHENY AVE.
VENANGO ST.
LEWIS & BALFOUR STS.
NORTHEAST SEWAGE PUMPING STATION
LEWIS & BALFOUR STS.
ORTHODOX & BALFOUR STS.
FRANKFORD CREEK
LARDNER ST.
MAGEE ST.
COTTMAN ST.
PENNYPACK CREEK COLLECTOR
PENNYPACK CREEK PUMPING STATION
PENNYPACK CREEK
ASHBURNER ST.
MILNOR ST. PUMPING STATION
STEVENSON ST.
FRANKFORD AVE.
PRINCETON AVE.
PENNYPACK CREEK PUMPING STATION
PROPOSED NORTHEAST SEWAGE TREATMENT WORKS
"L"
"C"
LEGEND
EXISTING SEWERS
PROPOSED SEWERS
PROPOSED COLLECTORS
NOTE:-
LETTERED POINTS ["G" "E" Etc.] ON PROFILES REFER TO CORRESPONDING POINTS ON PLAN
CITY OF PHILADELPHIA
PLAN FOR THE COLLECTION, TREATMENT AND DISPOSAL OF SEWAGE
NORTHEAST DIVISION COLLECTORS
HORIZONTAL SCALE OF FEET
0 1000 2000 4000 6000
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
1914

Furthermore, the mere interception of the sewage along the Delaware River front above the northeast works and its discharge below Bridesburg affords a considerable protection to the source of the water supply, for under this condition the ebbing tide carries the sewage down stream and away from the Torresdale intake for nearly 60 per cent. of the day. And during the remaining 40 per cent. of the time only the effluent discharged during the beginning of the flood tide can ever reach as far up stream as the water intake.

When the volume of sewage increases to a quantity such that additional treatment will be required to maintain hygienic conditions, it will be necessary to resort to oxidation. At the present time, the most successful process for this purpose is the percolating filter and it is very probable that the rapid advances in the art of sewage treatment will develop improvements whereby higher rates of filtration may be used and also, less head required. It is also possible that an entirely new process may be developed for sewage oxidation.

The Emscher tanks should, therefore, be built at such an elevation and in such locations that the effluent of the tanks can be passed through percolating filters for which ample ground should be provided as above recommended.

Disposal

In order to accomplish the diffusion of the effluent with the water of the Delaware River so that natural biological forces shall continue its purification, which will have begun in the artificial works, submerged outfalls should be laid from the treatment works to the channel of the river; these should terminate in several outlets to accomplish complete diffusion of the effluent with the river water.

The Southwest Division

Collection

After careful study of many projects and making the collection of the maximum amount of sewage without pumping a controlling policy, it has been decided that the main gravity collector for this division should begin at Front and Huntingdon Streets (M), where it will gather sewage from the upper part of the Aramingo sewer system; thence the alignment should be in a southerly direction crossing the Cohocksink sewer system and passing over the proposed Broad Street subway at Callowhill Street. It should then be carried out Callowhill Street to Twenty-first Street (P) and thence approximately parallel to the Schuylkill River to Reed Street (Q), where the sewage should be carried under the river in an inverted siphon; a short spur would collect by gravity the sewage from the Mill Creek drainage area and another spur along Sixtieth Street would collect by gravity the sewage from the upper part of the present Cobbs Creek collector (S). These two spurs would collect most of the sewage of West Philadelphia. The main gravity collector should be carried to the vicinity of the west end of Penrose Ferry bridge (U) where coarse screens and grit chambers would remove the larger floating matter and the sand, after which the sewage would flow by gravity to the site of the Southwest Treatment Works.

It is estimated that in 1950 this collector will deliver without pumping the sewage of 651,000 people, amounting to 159,000,000 gallons per day.

For the collection of the sewage from those parts of the Southwest division of the city at too low elevations to be gathered directly by the main gravity collector; low level collectors should be constructed parallel to the Delaware River between the outlet of the Aramingo system at Dyott Street (N) and the sewer on the north side of Market

Street. These collectors would deliver the sewage to a pumping station in the vicinity of Front and Green Streets, where it would be raised through a short force main and flow west on Green Street to the main gravity collector.

It is estimated that this low level system will collect in 1950 the sewage of 189,000 persons, amounting to 61,000,000 gallons per day.

A pumping station should be located on the east bank of the Schuylkill River in the vicinity of Callowhill Street (O) to lift into the main gravity collector (at P) sewage from the northeast part of Chestnut Hill, Roxborough, Wissahickon, Manayunk and Falls of Schuylkill, flowing in the present intercepting sewer to below Fairmount dam; also sewage gathered by a collector from the combined sewers now discharging into the Schuylkill on the east side of the river above Market Street; also sewage gathered by a high level collector from that part of West Philadelphia between the Mill Creek drainage area and Thirtieth Street, and by a low level collector along the west bank of the Schuylkill River to gather the abattoir drainage.

This West Philadelphia sewage should be carried under the river by an inverted siphon and would rise to different levels in the pumping station (O), thereby conserving the potential energy of the sewage from the higher land.

It is estimated that in 1950 this pumping station will lift into the main gravity collector the sewage of 347,000 people, amounting to 107,000,000 gallons per day.

On the east bank of the Schuylkill at the head of the inverted siphon at Reed Street (Q) a pumping station should be constructed to lift into the main gravity collector the sewage gathered from sewer outlets on the east bank of the river between Market Street and Passyunk Avenue (R) by low level collectors and the sewage from the area on the west bank of the Schuylkill between the main gravity collector and the river which should be

gathered by a low level collector and carried under the river in an inverted siphon placed in a different tube, but part of the same construction, which would carry the sewage of the main gravity collector in an opposite direction.

It is estimated that this pumping station would add in 1950 to the main gravity collector the sewage of 228,000 persons, amounting to 42,000,000 gallons per day.

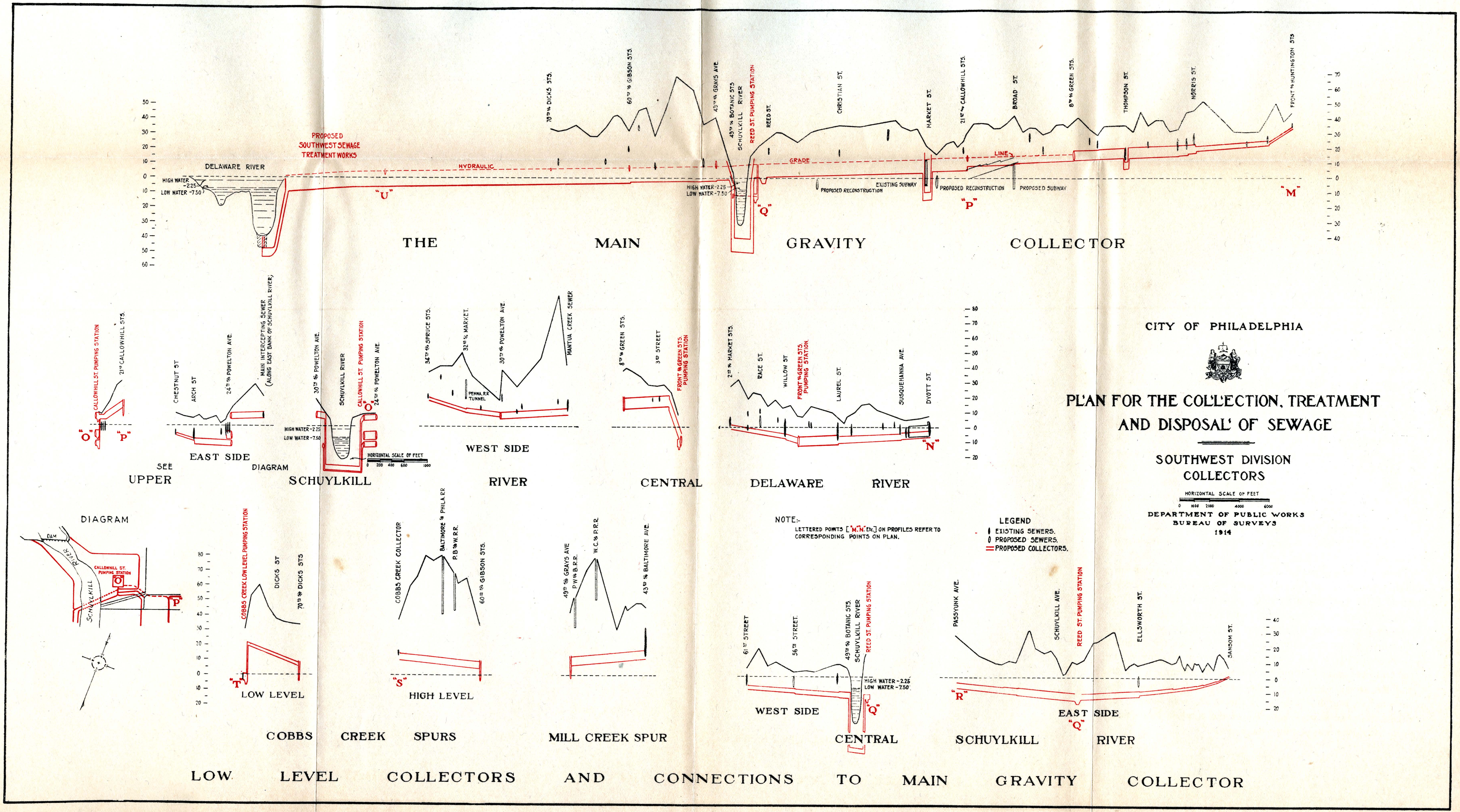
At the present outlet of the existing Cobbs Creek collector (T) a pumping station should be constructed to lift into the main gravity collector the sewage gathered by the Cobbs Creek collector below Sixtieth Street (S).

It is estimated that this pumping station would add in 1950 to the main gravity collector the sewage from 15,000 people, amounting to 3,000,000 gallons per day.

That part of the City south of Oregon Avenue and west of Broad Street is lowland, and it is advisable to place tide-gates at the sewer outlets and construct low level collectors along the east bank of the Schuylkill River to carry the sewage to the vicinity of Penrose Ferry, where it would pass under the river in an inverted siphon to a pumping station (U) on the west bank.

It is estimated that in 1950 these sewers would collect the sewage of 71,000 people, amounting to 12,000,000 gallons per day.

The natural surface of the southwest portion of the Fortieth ward is at an elevation below high tide, and is protected from inundation by dikes along the river front. A separate system of sewage and storm water conduits has been designed for this territory. The sewage sewers would all converge at the pumping station (U) in the vicinity of Penrose Ferry, where the sewage would be pumped to the gravity sewer leading to the nearby treatment works and the storm water would be stored in large reservoirs for discharge at low tide or if the storm was intense the excess over the storage capacity of the conduits and reservoirs would be pumped into the river.



CITY OF PHILADELPHIA
PLAN FOR THE COLLECTION, TREATMENT AND DISPOSAL OF SEWAGE
SOUTHWEST DIVISION COLLECTORS
HORIZONTAL SCALE OF FEET
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
1914
THE MAIN GRAVITY COLLECTOR
PROPOSED SOUTHWEST SEWAGE TREATMENT WORKS
DELAWARE RIVER
HIGH WATER -2.25
LOW WATER -7.50
HYDRAULIC GRADE LINE
"U"
"Q"
"P"
"M"
70TH & DICKS STS.
60TH & GIBSON STS.
49TH & GRAYS AVE.
49TH & BOTANIC STS.
SCHUYLKILL RIVER
REED ST. PUMPING STATION
REED ST.
CHRISTIAN ST.
MARKET ST.
21ST & CALLOWHILL STS.
BROAD ST.
8TH & GREEN STS.
THOMPSON ST.
NORRIS ST.
FRONT & HUNTINGTON STS.
PROPOSED RECONSTRUCTION
EXISTING SUBWAY
PROPOSED SUBWAY
UPPER SCHUYLKILL
EAST SIDE
SEE DIAGRAM
CALLOWHILL ST. PUMPING STATION
21ST & CALLOWHILL STS.
CHESTNUT ST.
ARCH ST.
24TH & POWELTON AVE.
MAIN INTERCEPTING SEWER (ALONG EAST BANK OF SCHUYLKILL RIVER)
"O"
30TH & POWELTON AVE.
24TH & POWELTON AVE.
WEST SIDE
34TH & SPRUCE STS.
32ND & MARKET
PENNA. R.R. TUNNEL
30TH & POWELTON AVE.
MANTUA CREEK SEWER
RIVER
CENTRAL DELAWARE RIVER
8TH & GREEN STS.
3RD STREET
FRONT & GREEN STS. PUMPING STATION
2ND & MARKET STS.
RACE ST.
WILLOW ST.
LAUREL ST.
SUSQUEHANNA AVE.
DYOTT ST.
"N"
NOTE:- LETTERED POINTS ["M","N", Etc.] ON PROFILES REFER TO CORRESPONDING POINTS ON PLAN.
LEGEND
EXISTING SEWERS.
PROPOSED SEWERS.
PROPOSED COLLECTORS.
DIAGRAM
DAM
RIVER
SCHUYLKILL
CALLOWHILL ST. PUMPING STATION
COBBS CREEK SPURS
LOW LEVEL
COBBS CREEK LOW LEVEL PUMPING STATION
DICKS ST.
70TH & DICKS STS.
"T"
HIGH LEVEL
COBBS CREEK COLLECTOR
BALTIMORE & PHILA. R.R.
P.B. & W. R.R.
60TH & GIBSON STS.
"S"
MILL CREEK SPUR
49TH & GRAYS AVE.
PW. & B. R.R.
W.C. & P.R.R.
43RD & BALTIMORE AVE.
CENTRAL SCHUYLKILL RIVER
WEST SIDE
61ST STREET
56TH STREET
49TH & BOTANIC STS.
SCHUYLKILL RIVER
REED ST. PUMPING STATION
EAST SIDE
PASSYUNK AVE.
SCHUYLKILL AVE.
REED ST. PUMPING STATION
ELLSWORTH ST.
SANSOM ST.
"R"
LOW LEVEL COLLECTORS AND CONNECTIONS TO MAIN GRAVITY COLLECTOR

It is estimated that in 1950 the sewage pumping station at Penrose Ferry would lift the sewage of 233,000 persons, amounting to 45,000,000 gallons per day, including the infiltrated ground water from the lowland sewer system.

Treatment Works

The city owns 400 acres of land in the lower part of the Fortieth ward, known as the Cannon Ball farm, and additional land in the vicinity should be obtained sufficient in area for the Southwest Treatment Works.

On the eastern side of this tract there should be located two-story sedimentation tanks of the Emscher type with sludge drying beds for the treatment of sewage collected from the southwest division of the city.

The remainder of the tract will be utilized for the construction of the necessary works for the oxidation of the settled sewage, when that refinement is needed to maintain the Delaware River in a clean condition.

When such works are constructed a pumping station will be required to lift the tank effluent to a sufficient height to pass through the oxidizing works.

It is estimated that the treatment works at this site will receive in 1950 the sewage of 1,663,000 persons, amounting to 417,000,000 gallons per day.

Disposal

An Act is now before Congress to give the city the right to construct conduits, wharf, and road across the Government property in order that the effluent of these works may be discharged through submerged outfalls into the channel of the Delaware River.

The site of the Southwest Works is lowland and affords ample space for the use of the dried sludge for filling to bring the tract up to the elevation required for future development.

The Southeast Division

Collection

Low level collectors should be constructed to gather sewage from sewers discharging into the Delaware River between Market Street and the proposed railroad freight terminal yards. They would join near Greenwich Point in the vicinity of Curtin Street and the Delaware River.

Treatment

Sufficient ground should be obtained to permit of the construction of a pumping station and sedimentation tanks at this place, but when it is considered that 90 per cent. of the sewage of the city will be carried to the Northeast and Southwest Works and treated before its discharge into the Delaware, it is deemed advisable to install at the Southeast Works fine screens, as the initial construction costs would be less than for tanks.

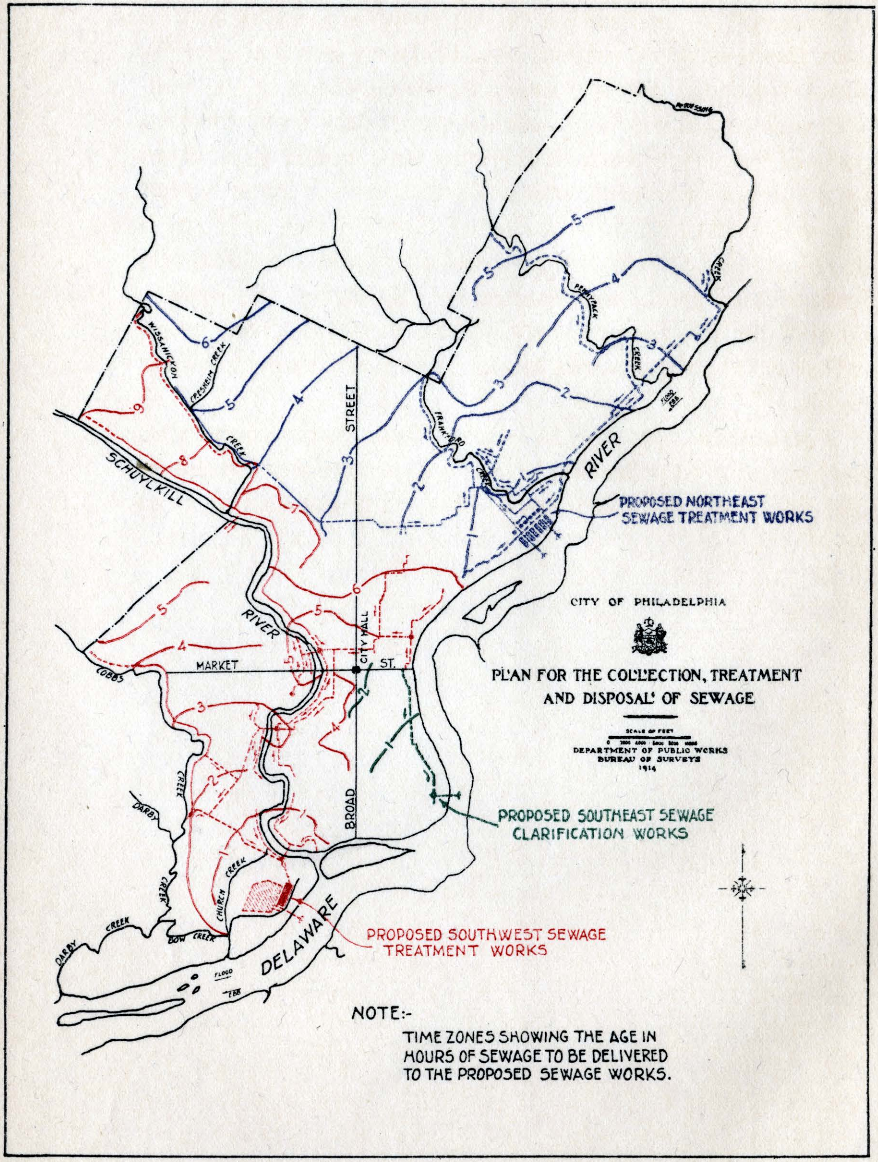
If, in the future, it is found that the sewage brought to these works requires more complete treatment to maintain the Delaware in a clean condition, tanks could be installed or the sewage carried over to the Southwest Works.

Disposal

After the sewage has been passed through the fine screens a low lift pumping station would be required to lift it to a sufficient elevation that it could be discharged through submerged outfalls to the channel of the Delaware River.

It is anticipated that this station will be surrounded by industrial establishments in the future, and it is deemed advisable to provide for the incineration of the screenings to prevent any nuisance in the neighborhood.

It is estimated that these works will receive in 1950 the sewage of 390,000 people, amounting to 82,000,000 gallons per day.


CITY OF PHILADELPHIA
PLAN FOR THE COLLECTION, TREATMENT AND DISPOSAL OF SEWAGE
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
1914
PROPOSED NORTHEAST SEWAGE TREATMENT WORKS
PROPOSED SOUTHEAST SEWAGE CLARIFICATION WORKS
PROPOSED SOUTHWEST SEWAGE TREATMENT WORKS
SCHUYLKILL
RIVER
DELAWARE
RIVER
MARKET
ST.
BROAD
STREET
CITY HALL
WISSAHICKON
CRESHEIM CREEK
CREEK
FRANKFORD
CREEK
PENNYPACK
CREEK
CREEK
COBBS
DARBY
CREEK
DARBY
CREEK
CHURCH CREEK
BOW CREEK
DARBY
CREEK
FLOOD
EBB
FLOOD
EBB
NOTE:-
TIME ZONES SHOWING THE AGE IN HOURS OF SEWAGE TO BE DELIVERED TO THE PROPOSED SEWAGE WORKS.

Time Zones

An important consideration in the design of the collecting system and in the location of the treatment works was to treat the sewage of the city as quickly as possible after its initial discharge into the general sewer system of the city.

On the accompanying plan the time of flow from different parts of the city to each of the treatment works is indicated by the different colored lines. This shows for instance that the major part of the sewage of Germantown will reach the Northeast Works within three hours and should, therefore, still be fresh and inodorous. Similarly, the sewage from West Philadelphia collected by the Mill Creek sewer will reach the Southwest Works in between three and four hours.

The sewage from the Delaware River front tributary to the Southeast Clarification Works will not be over two hours old, which is an important condition if fine screening is to be effective.

RECOMMENDED ORDER OF PROCEDURE FOR THE COLLECTION AND TREATMENT OF THE SEWAGE

FIRST RECOMMENDATION.

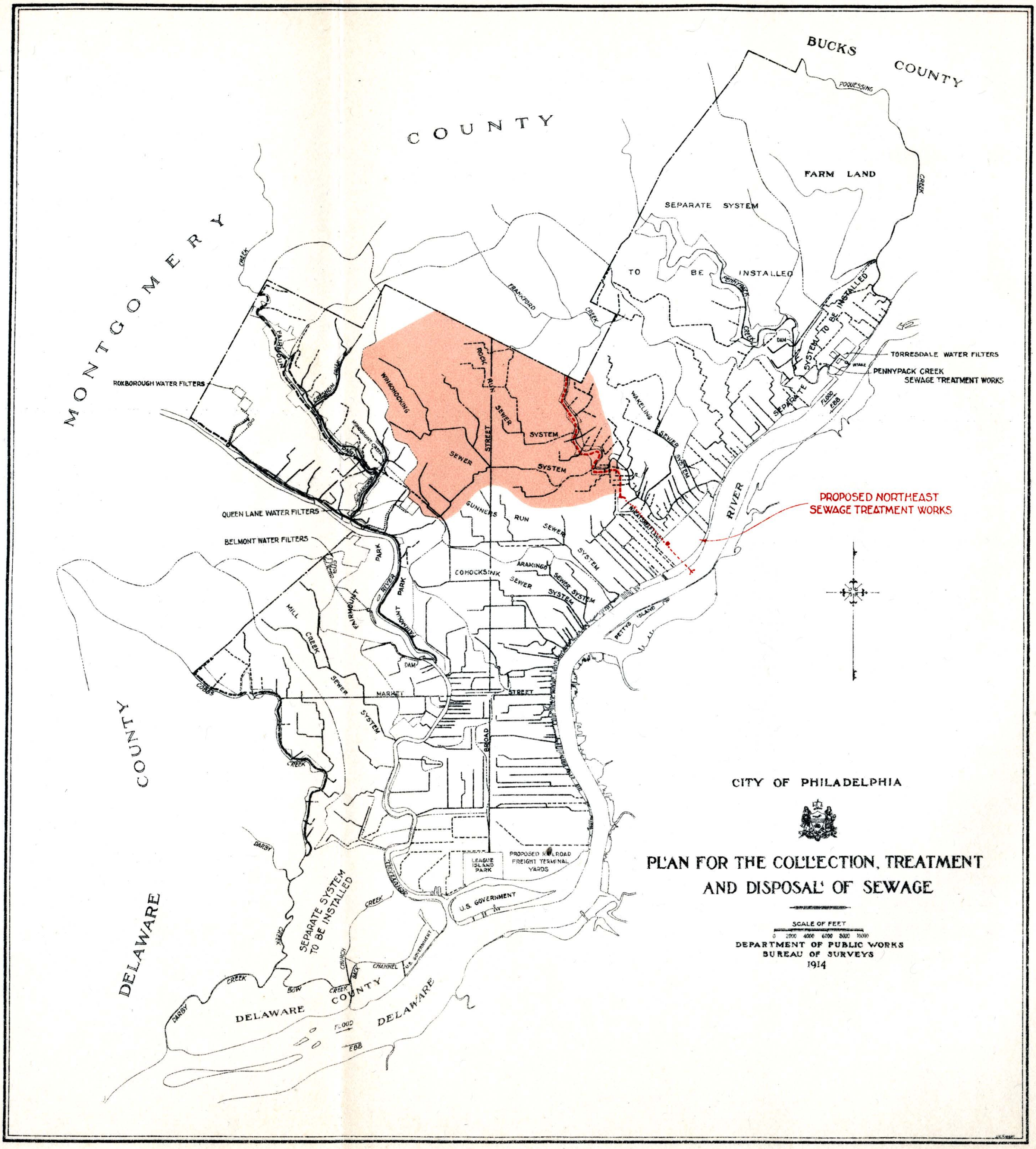
The purchase of the land required for the Northeast, Southwest and Southeast Treatment Works, in order that it be obtained at minimum expense prior to its development by private owners. It is estimated that this will require the expenditure of $1,700,000.

SECOND RECOMMENDATION

The construction of Frankford Creek high level collector between county line and the vicinity of O and Luzerne Streets; grit chamber, coarse screens and excess storm water overflow at that point; the two smaller tubes of the inverted siphon to the site of the Northeast Works; sedimentation tanks with sludge drying beds and appurtenances; and submerged outfall to the channel of the Delaware River at the Northeast Works.

The completion of these works will maintain the upper reaches of Frankford Creek in a clean condition, alleviate the grossly polluted condition of the lower reaches of the creek by the removal from it of the sewage of Germantown; and the treatment of the sewage before its discharge into the Delaware River will be a protection to the source of the water supply.

It is estimated that the construction of these works will cost $1,400,000, and provide for the collection and treatment of the sewage of 170,000 persons amounting to 40,000,000 gallons a day.



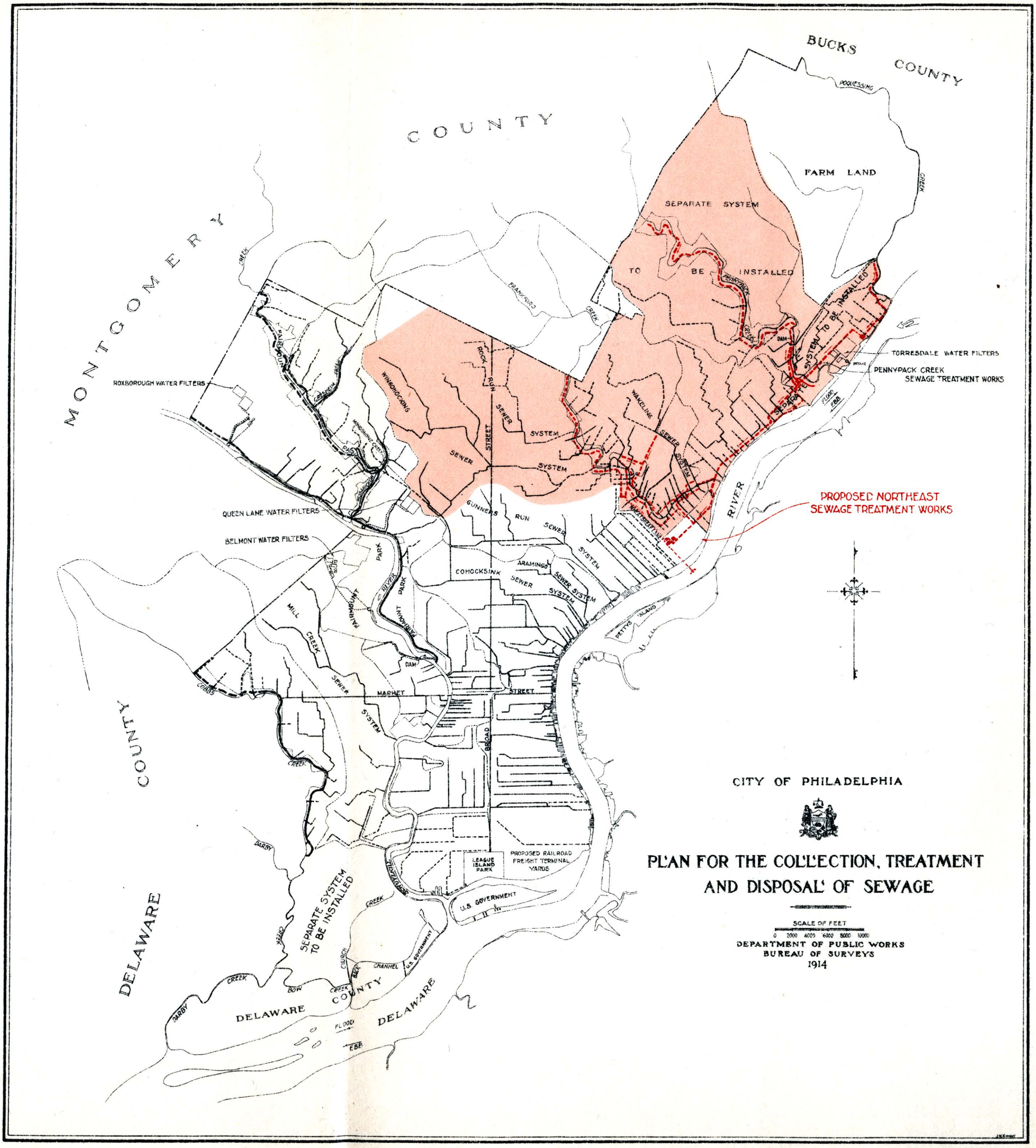
CITY OF PHILADELPHIA
PLAN FOR THE COLLECTION, TREATMENT AND DISPOSAL OF SEWAGE
SCALE OF FEET
0 2000 4000 6000 8000 10000
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
1914
PROPOSED NORTHEAST SEWAGE TREATMENT WORKS
BUCKS COUNTY
MONTGOMERY COUNTY
DELAWARE COUNTY
FARM LAND
SEPARATE SYSTEM TO BE INSTALLED
SEPARATE SYSTEM TO BE INSTALLED
SEPARATE SYSTEM TO BE INSTALLED
TORRESDALE WATER FILTERS
PENNYPACK CREEK SEWAGE TREATMENT WORKS
ROXBOROUGH WATER FILTERS
QUEEN LANE WATER FILTERS
BELMONT WATER FILTERS
WINGOHOCKING SEWER SYSTEM
ROCK RUN SEWER SYSTEM
WAKELING SEWER SYSTEM
GUNNERS RUN SEWER SYSTEM
ARAMINGO SEWER SYSTEM
COHOCKSINK SEWER SYSTEM
MILL CREEK SEWER SYSTEM
FAIRMOUNT PARK
RIVER
FRANKFORD CREEK
PENNYPACK CREEK
POQUESSING
MARKET STREET
BROAD STREET
PETTYS ISLAND
LEAGUE ISLAND PARK
PROPOSED RAILROAD FREIGHT TERMINAL YARDS
U.S. GOVERNMENT
DARBY CREEK
COBBS CREEK
BOW CREEK
CHURCH CREEK
BACK CHANNEL
DELAWARE RIVER
FLOOD
EBB
DAM

THIRD RECOMMENDATION

The construction of the upper Delaware low level collector between Poquessing Creek and the site of the Northeast Works, with pumping station in the vicinity of Milnor and Linden Streets, enlargement of the present Pennypack Creek sewage pumping station, and grit chamber screens and pumping station at the Northeast Works; collector along the Pennypack Creek between county line and the Delaware; low level collectors along the north and south sides of Frankford Creek; the Wakeling Street high level collector between Pratt and Leiper Streets and the vicinity of O and Luzerne Streets; additional sedimentation tanks with sludge drying beds and appurtenances at the Northeast Works.

The completion of these works will maintain Frankford and Pennypack Creeks in a clean condition; prevent the discharge of crude sewage into the Delaware River between Bridesburg and northern boundary of the city; and the treatment of the sewage so collected will maintain the water of the Delaware River as a fit source of water supply.

It is estimated that the construction of these works will cost $1,900,000, and when completed the Northeast Works will be capable of treating the sewage of 300,000 persons amounting to 70,000,000 gallons a day.



BUCKS COUNTY
MONTGOMERY COUNTY
DELAWARE COUNTY
FARM LAND
SEPARATE SYSTEM TO BE INSTALLED
WINGOHOCKING SEWER SYSTEM
ROCK RUN SEWER SYSTEM
WAKELINE SEWER SYSTEM
GUNNERS RUN SEWER SYSTEM
COHOCKSINK SEWER SYSTEM
ARAMINGO SEWER SYSTEM
MILL CREEK SEWER SYSTEM
SEPARATE SYSTEM TO BE INSTALLED
ROXBOROUGH WATER FILTERS
QUEEN LANE WATER FILTERS
BELMONT WATER FILTERS
TORRESDALE WATER FILTERS
PENNYPACK CREEK SEWAGE TREATMENT WORKS
PROPOSED NORTHEAST SEWAGE TREATMENT WORKS
RIVER
PETTYS ISLAND
MARKET STREET
BROAD STREET
FAIRMOUNT PARK
DAM
LEAGUE ISLAND PARK
PROPOSED RAILROAD FREIGHT TERMINAL YARDS
U.S. GOVERNMENT
DELAWARE
FLOOD
EBB
CITY OF PHILADELPHIA
PLAN FOR THE COLLECTION, TREATMENT AND DISPOSAL OF SEWAGE
SCALE OF FEET
0 2000 4000 6000 8000 10000
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
1914

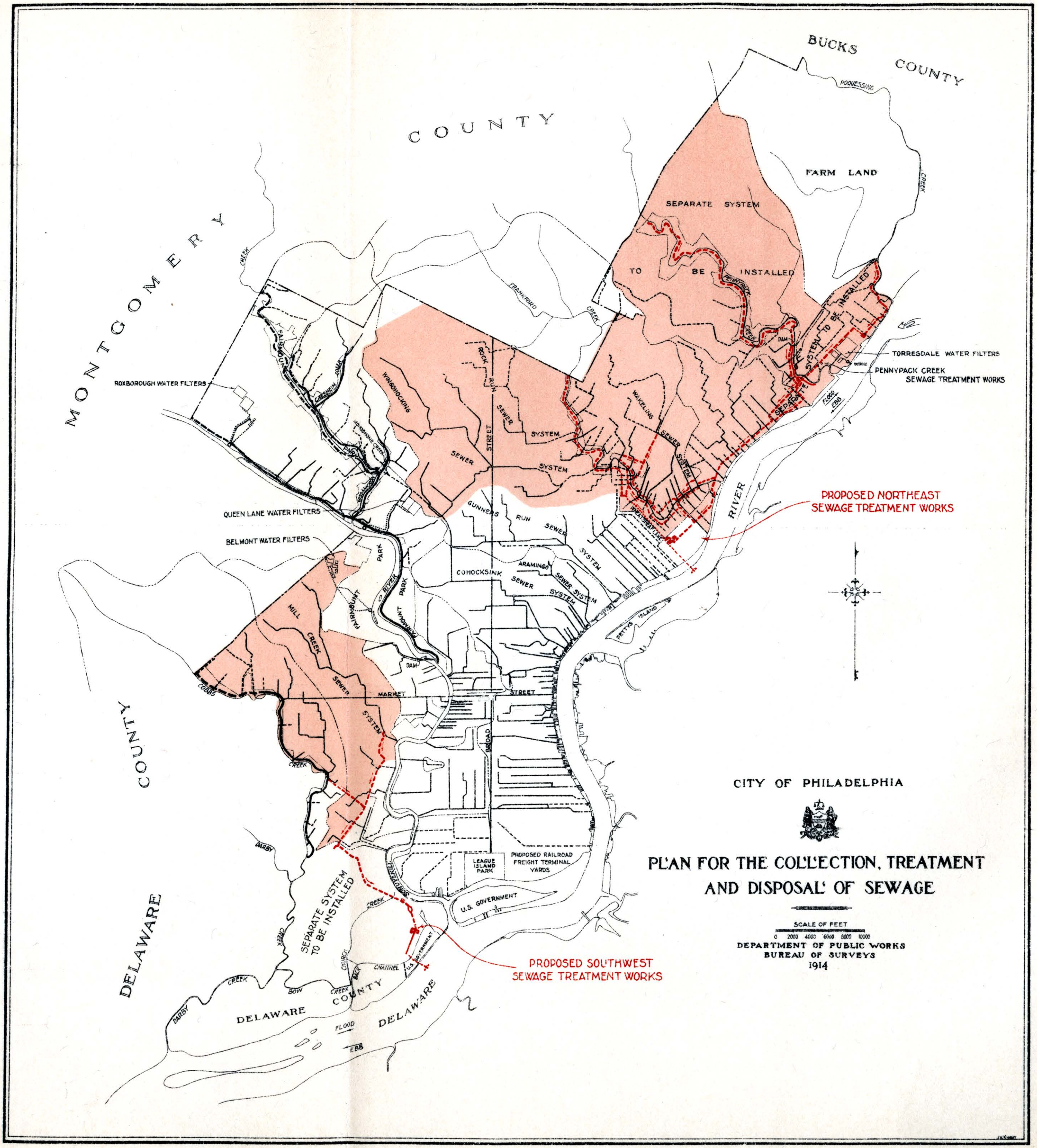
FOURTH RECOMMENDATION

The purity of the city's water supply is of vital importance to the entire community. The works previously recommended and those already built are intended to safeguard the sources of the water supply.

It is next recommended that the main gravity collector between the Mill Creek sewer and the Southwest Works be constructed with a spur to collect sewage from the existing Cobbs Creek collector; coarse screens and grit chamber in the vicinity of Penrose Ferry; a conduit to and through the Southwest Works; sedimentation tanks with sludge drying beds and appurtenances; and submerged outfall to the channel of the Delaware River.

The completion of these works will lessen the pollution of the lower Schuylkill River by preventing the discharge into it of the sewage of a large part of West Philadelphia and the treatment of the sewage will prevent the creation of nuisance otherwise caused by the discharge of this crude sewage into the Delaware River.

It is estimated that the construction of these works will cost $5,700,000 and when completed the Southwest Works will be capable of treating the sewage of 240,000 people amounting to 55,000,000 gallons a day.



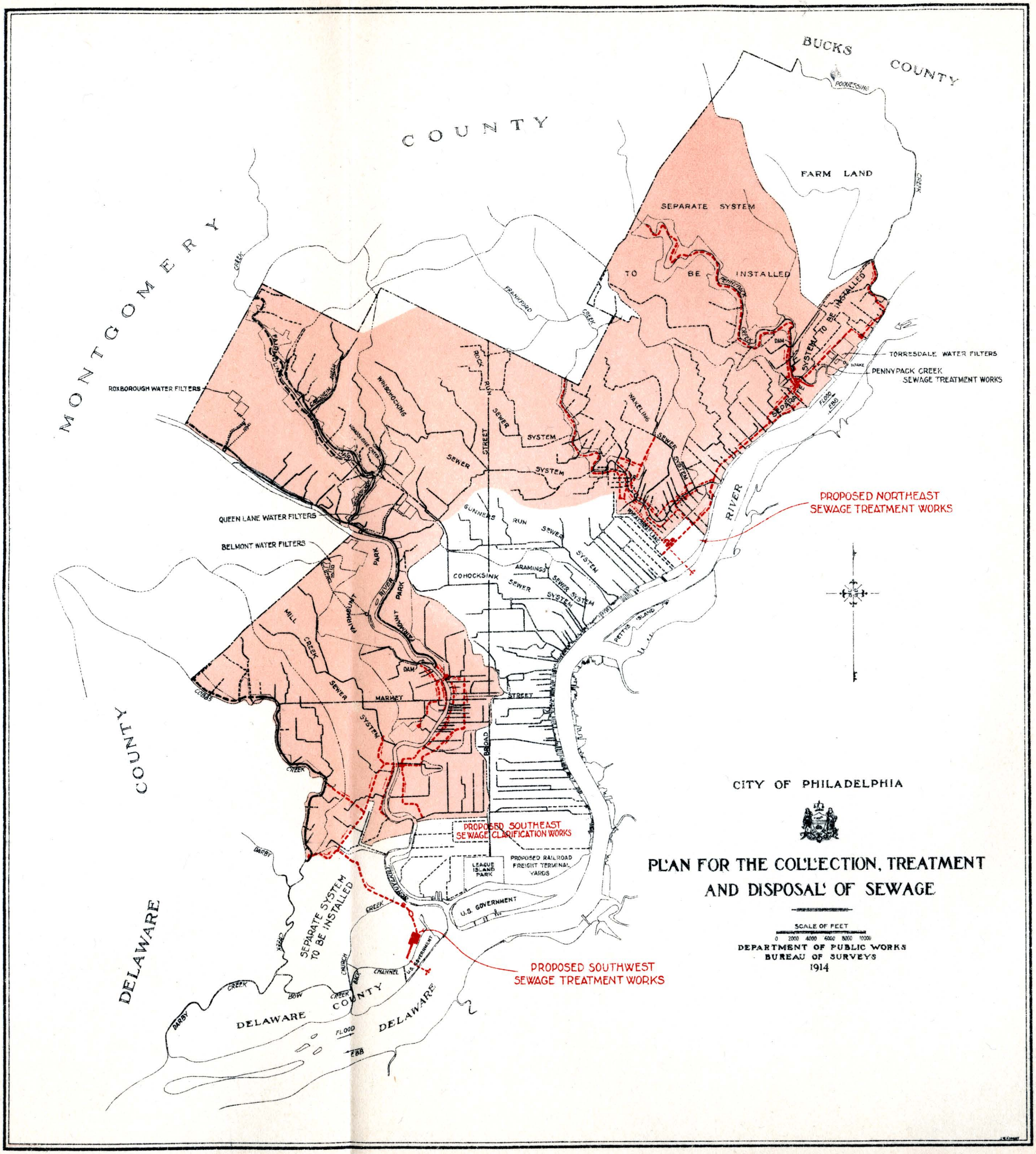
CITY OF PHILADELPHIA
PLAN FOR THE COLLECTION, TREATMENT AND DISPOSAL OF SEWAGE
SCALE OF FEET
0 2000 4000 6000 8000 10000
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
1914
BUCKS COUNTY
MONTGOMERY COUNTY
DELAWARE COUNTY
FARM LAND
SEPARATE SYSTEM TO BE INSTALLED
SEPARATE SYSTEM TO BE INSTALLED
TORRESDALE WATER FILTERS
PENNYPACK CREEK SEWAGE TREATMENT WORKS
PROPOSED NORTHEAST SEWAGE TREATMENT WORKS
ROXBOROUGH WATER FILTERS
QUEEN LANE WATER FILTERS
BELMONT WATER FILTERS
WINGOHOCKING SEWER SYSTEM
ROCK RUN SEWER SYSTEM
WAKELING SEWER SYSTEM
GUNNERS RUN SEWER SYSTEM
COHOCKSINK SEWER SYSTEM
ARAMINGO SEWER SYSTEM
MILL CREEK SEWER SYSTEM
FAIRMOUNT PARK
MARKET STREET
BROAD STREET
PETTYS ISLAND
LEAGUE ISLAND PARK
PROPOSED RAILROAD FREIGHT TERMINAL YARDS
U.S. GOVERNMENT
SEPARATE SYSTEM TO BE INSTALLED
PROPOSED SOUTHWEST SEWAGE TREATMENT WORKS
RIVER
DELAWARE
FLOOD
EBB
DARBY CREEK
COBBS CREEK
FRANKFORD CREEK
PENNYPACK CREEK
POQUESSING CREEK
BOW CREEK
BACK CHANNEL
CHURCH CREEK
DAM

FIFTH RECOMMENDATION

The construction of the Reed Street siphon under the Schuylkill River and extension of the main gravity collector to the vicinity of Twenty-first and Callowhill Streets; grit chambers, coarse screens, and pumping stations on the east bank of the Schuylkill River at Callowhill and Reed Streets and on Cobbs Creek at the outlet of the present Cobbs Creek collector; connections between these pumping stations and the main gravity collector; the upper and central Schuylkill River low level collectors; and enlargement of the Southwest Works by construction of additional sedimentation tanks, sludge drying beds and appurtenances.

The completion of these works will prevent the discharge of crude sewage into the Schuylkill River above Passyunk Avenue and as but few sewers are now built below this point it will maintain the Schuylkill River in a clean condition.

It is estimated that the construction of these works will cost $4,800,000, and when completed the Southwest Works will be capable of treating the sewage of 668,000 persons, amounting to 175,000,000 gallons a day.



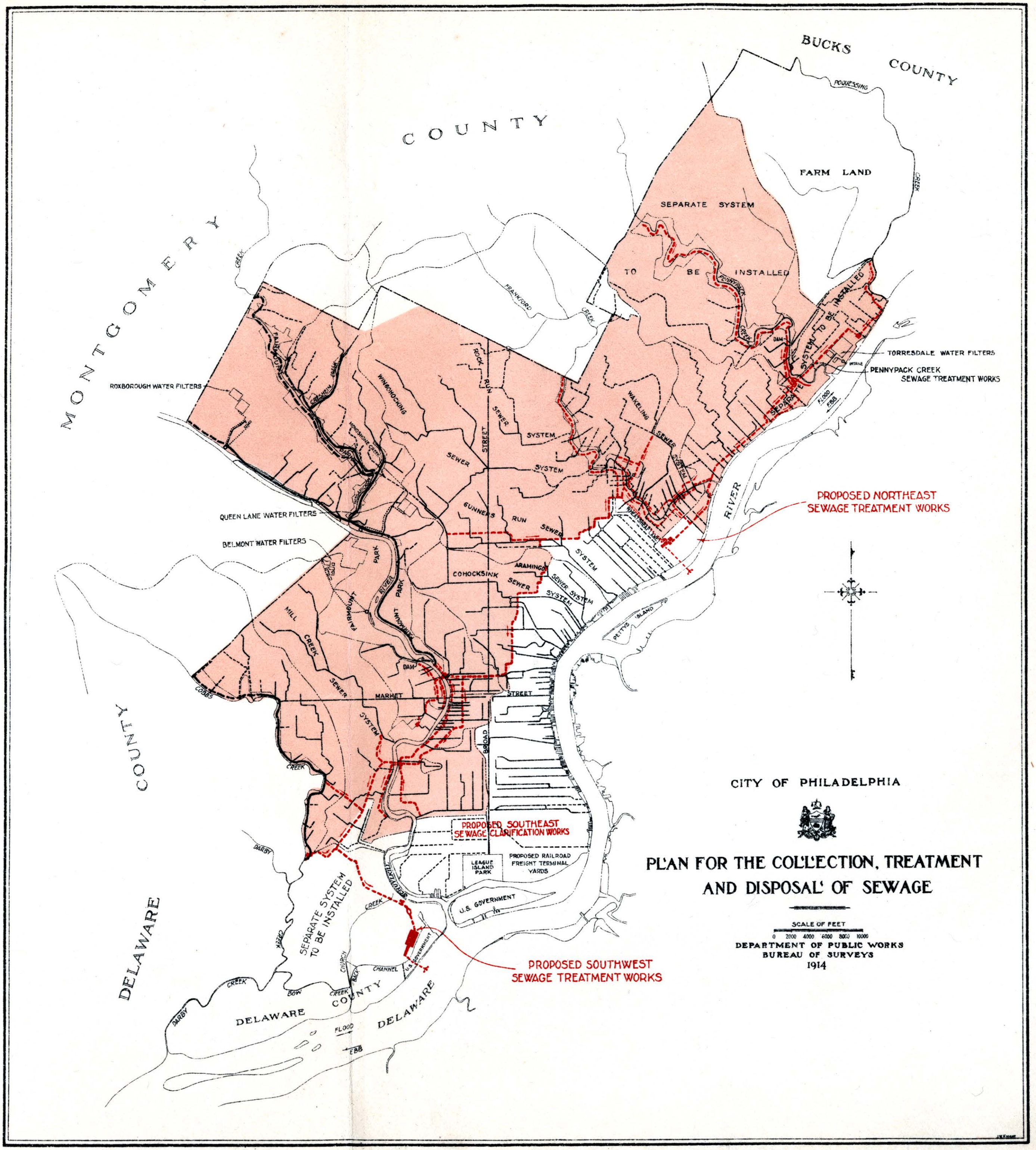
BUCKS COUNTY
MONTGOMERY COUNTY
DELAWARE COUNTY
FARM LAND
SEPARATE SYSTEM TO BE INSTALLED
ROXBOROUGH WATER FILTERS
QUEEN LANE WATER FILTERS
BELMONT WATER FILTERS
TORRESDALE WATER FILTERS
PENNYPACK CREEK SEWAGE TREATMENT WORKS
PROPOSED NORTHEAST SEWAGE TREATMENT WORKS
ROCK RUN SEWER SYSTEM
WINGOHOCKING SEWER SYSTEM
WAKELING SEWER SYSTEM
GUNNERS RUN SEWER SYSTEM
COHOCKSINK SEWER SYSTEM
ARAMINGO SEWER SYSTEM
MILL CREEK SEWER SYSTEM
FAIRMOUNT PARK
RIVER
DAM
MARKET STREET
BROAD STREET
PROPOSED SOUTHEAST SEWAGE CLARIFICATION WORKS
PROPOSED RAILROAD FREIGHT TERMINAL YARDS
LEAGUE ISLAND PARK
U.S. GOVERNMENT
PROPOSED SOUTHWEST SEWAGE TREATMENT WORKS
PETTYS ISLAND
DARBY CREEK
BOW CREEK
DELAWARE
FLOOD
EBB
CITY OF PHILADELPHIA
PLAN FOR THE COLLECTION, TREATMENT AND DISPOSAL OF SEWAGE
SCALE OF FEET
0 2000 4000 6000 8000 10000
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
1914

SIXTH RECOMMENDATION.

The construction of the Wissahickon and Gunners Run high level collector between Twenty-fourth and Westmoreland Streets and the vicinity of O and Luzerne Streets with the Gunners Run spur in Second Street between Indiana and Allegheny Avenues; the completion of the main gravity collector by its extension to Front and Huntingdon Streets; the enlargement of the Northeast and Southwest Works by the construction of additional sedimentation tanks, sludge drying beds and appurtenances.

The completion of these works will reduce the amount of crude sewage discharged into the Delaware River below Bridesburg, but involves no additional pumping. The treatment of the sewage at the Northeast Works will protect the source of water supply taken at Torresdale and at the Southwest will maintain the water of the Delaware River in a clean condition.

It is estimated that the construction of the works recommended above will cost, $3,400,000 and when the above extensions have been completed the Northeast Works will be capable of treating the sewage of 468,000 persons, amounting to 100,000,000 gallons a day, and the Southwest Works of treating the sewage of 924,000 persons, amounting to 236,000,000 gallons a day.

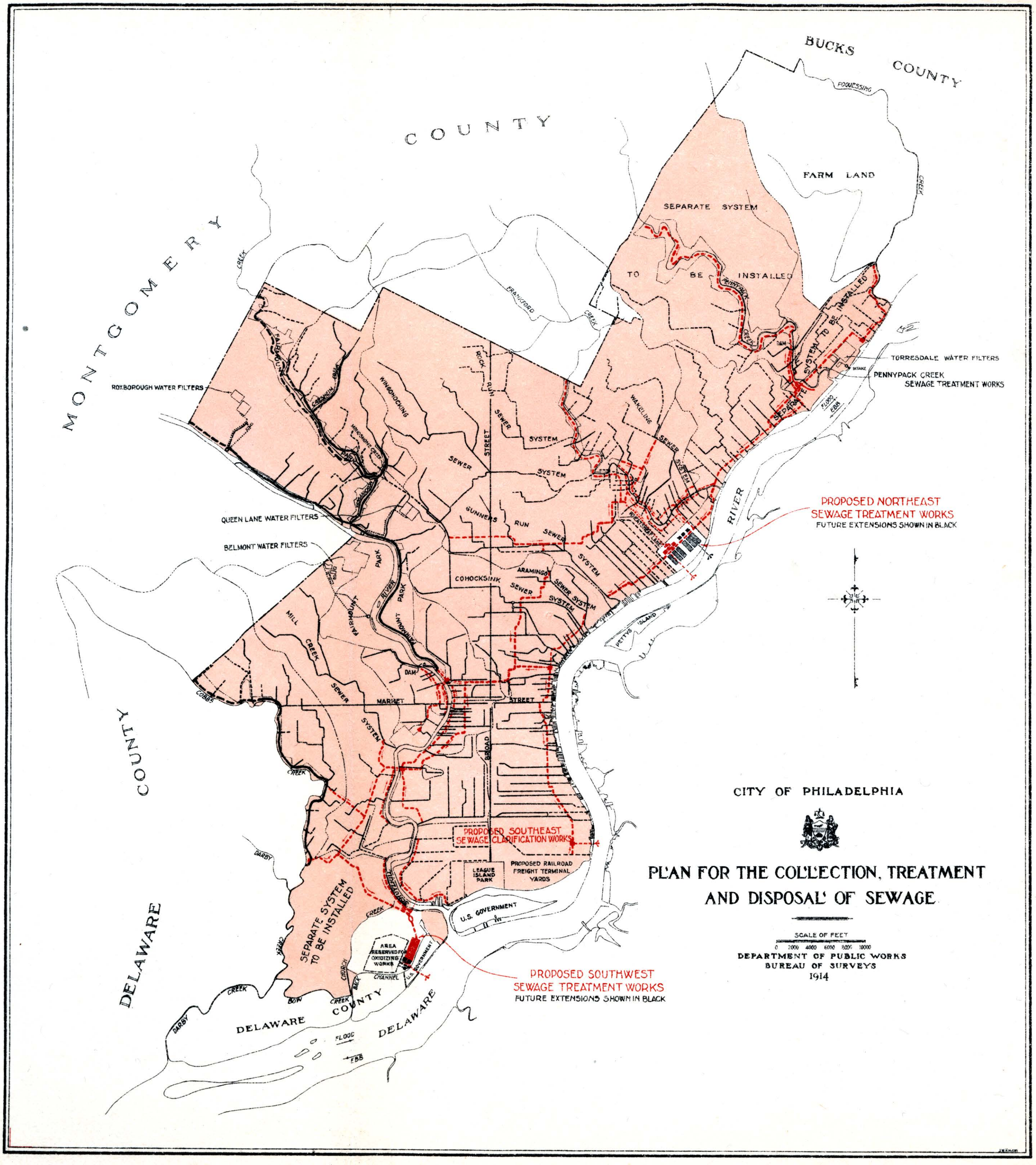

CITY OF PHILADELPHIA
PLAN FOR THE COLLECTION, TREATMENT AND DISPOSAL OF SEWAGE
SCALE OF FEET
0 2000 4000 6000 8000 10000
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
1914
BUCKS COUNTY
MONTGOMERY COUNTY
DELAWARE COUNTY
FARM LAND
SEPARATE SYSTEM TO BE INSTALLED
POQUESSING CREEK
PENNYPACK CREEK
FRANKFORD CREEK
TORRESDALE WATER FILTERS
PENNYPACK CREEK SEWAGE TREATMENT WORKS
PROPOSED NORTHEAST SEWAGE TREATMENT WORKS
PROPOSED SOUTHEAST SEWAGE CLARIFICATION WORKS
PROPOSED SOUTHWEST SEWAGE TREATMENT WORKS
ROXBOROUGH WATER FILTERS
QUEEN LANE WATER FILTERS
BELMONT WATER FILTERS
WINGOHOCKING SEWER SYSTEM
ROCK RUN SEWER SYSTEM
WAKELING SEWER SYSTEM
GUNNERS RUN SEWER SYSTEM
COHOCKSINK SEWER
ARAMINGO SEWER SYSTEM
MILL CREEK SEWER SYSTEM
FAIRMOUNT PARK
RIVER
DAM
MARKET STREET
BROAD STREET
PETTYS ISLAND
LEAGUE ISLAND PARK
PROPOSED RAILROAD FREIGHT TERMINAL YARDS
U.S. GOVERNMENT
COBBS CREEK
DARBY CREEK
BOW CREEK
CHURCH CREEK
BACK CHANNEL
DELAWARE RIVER
FLOOD
EBB

SEVENTH RECOMMENDATION.

The construction of the Gunners Run low level collector, the central and lower Delaware low level collectors, the lower Schuylkill low level collector on the east side; the enlargement of the pumping station at the Northeast Works; the construction of grit chambers, coarse screens and pumping station at Green Street with connection to the main gravity collector; the construction of grit chamber, fine screens, pumping station and submerged outlet to the Delaware River at the site of the Southeast Clarification Works; the construction of a siphon under the Schuylkill River; grit chamber, coarse screens and pumping station at the west bank of the Schuylkill River in the vicinity of Penrose Ferry; and the enlargement of the Northeast and Southwest Works by the construction of additional sedimentation tanks, sludge drying beds and appurtenances.

It is estimated that these works will cost $3,500,000 and upon their completion the City of Philadelphia will be provided with a system of collectors so located and of sufficient size to intercept all the dry weather flow of sewage and first flush of rain water from the entire city under the conditions anticipated in 1950 (excepting the farm lands in the extreme northeastern end of the City). The Northeast Works will be capable of treating the sewage of 566,000 persons, amounting to 118,000,000 gallons a day; the Southeast, the sewage of 312,000 persons, amounting to 64,000,000 gallons a day, and the Southwest, the sewage of 1,200,000 persons, amounting to 313,000,000 gallons a day.

The collection and treatment of the sewage will maintain all the water courses of Philadelphia in a clean condition and protect the source of the city's water supply.



CITY OF PHILADELPHIA
PLAN FOR THE COLLECTION, TREATMENT AND DISPOSAL OF SEWAGE
SCALE OF FEET
0 2000 4000 6000 8000 10000
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
1914
BUCKS COUNTY
MONTGOMERY COUNTY
DELAWARE COUNTY
DELAWARE
DELAWARE RIVER
FARM LAND
SEPARATE SYSTEM TO BE INSTALLED
SEPARATE SYSTEM TO BE INSTALLED
TORRESDALE WATER FILTERS
PENNYPACK CREEK SEWAGE TREATMENT WORKS
ROXBOROUGH WATER FILTERS
QUEEN LANE WATER FILTERS
BELMONT WATER FILTERS
PROPOSED NORTHEAST SEWAGE TREATMENT WORKS
FUTURE EXTENSIONS SHOWN IN BLACK
WINGOHOCKING SEWER SYSTEM
ROCK RUN SEWER SYSTEM
WAKELING SEWER SYSTEM
GUNNERS RUN SEWER SYSTEM
COHOCKSINK SEWER SYSTEM
ARAMINGO SEWER SYSTEM
MILL CREEK SEWER SYSTEN
FAIRMOUNT PARK
MARKET STREET
BROAD STREET
PETTYS ISLAND
DAM
PROPOSED SOUTHEAST SEWAGE CLARIFICATION WORKS
LEAGUE ISLAND PARK
PROPOSED RAILROAD FREIGHT TERMINAL YARDS
U.S. GOVERNMENT
AREA RESERVED FOR OXIDIZING WORKS
PROPOSED SOUTHWEST SEWAGE TREATMENT WORKS
FUTURE EXTENSIONS SHOWN IN BLACK
CHANNEL
DARBY CREEK
COBBS CREEK
BOW CREEK
FLOOD
EBB
FRANKFORD CREEK
POQUESSING CREEK
PENNYPACK CREEK

CONCLUSION

It is anticipated that the increase in population, the growth in industry, the extension of the sewer system and the increasing standards of hygienic cleanliness of the future will require more refined treatment of the sewage at the Northeast and the Southwest Works than the removal of the settleable solids provided for in the preceding recommendations.

The most efficient process known to-day for meeting these conditions of the future consists of the percolating filter and the areas of land recommended to be purchased are sufficient for the installation of such beds. It is futile to anticipate the cost of materials and labor thirty-five years hence or to know how advances in the methods of oxidizing sewage may influence the cost of such works in 1950. But with present day knowledge it is estimated that the extensions to the works previously recommended consisting of additional sedimentation tanks with sludge drying beds, percolating filters and appurtenances sufficient to meet the requirements of the City of Philadelphia (within its present boundaries) in the year 1950 will cost an additional $12,200,000 making a total cost of the complete system of $34,600,000 for the interception of all sewage and the first flush of storm-water and its treatment by sedimentation with sludge digestion and oxidation of the settled sewage in percolating filters and the disposal of the clarified and oxidized effluent in the waters of the Delaware River through submerged outfalls.

GEORGE S. WEBSTER,
Chief Engineer,
GEORGE E. DATESMAN,
Principal Assistant Engineer,
W. L. STEVENSON,
Assistant Engineer.

APPENDIX A

AN ACT

To preserve the purity of the waters of the State, for the protection of the public health.

SECTION 1. *Be it enacted, etc.,* That the term "waters of the State," wherever used in this Act, shall include all streams and springs, and all bodies of surface and of ground water, whether natural or artificial, within the boundaries of the State.

SECTION 2. . . . .

SECTION 3. . . . .

SECTION 4. No person, corporation, or municipality shall place, or permit to be placed, or discharge, or permit to flow into any of the waters of the State, any sewage, except as hereinafter provided. But this Act shall not apply to waters pumped or flowing from coal mines or tanneries, nor prevent the discharge of sewage from any public sewer system, owned and maintained by a municipality, provided such sewer system was in operation and was discharging sewage into any of the waters of the State at the time of the passage of this Act. But this exception shall not permit the discharge of sewage from a sewer system which shall be extended subsequent to the passage of this Act.

For the purpose of this Act, sewage shall be defined as any substance that contains any of the waste products, or excrementitious or other discharges from the bodies of human being, or animals.

SECTION 5. Upon application duly made to the Commissioner of Health, by the public authorities having by law

the charge of the sewer system of any municipality, the Governor of the State, the Attorney General, and the Commissioner of Health shall consider the case of such a sewer system, otherwise prohibited by this Act from discharging sewage into any of the waters of the State, and, whenever it is their unanimous opinion that the general interests of the public health would be subserved thereby, the Commissioner of Health may issue a permit for the discharge of sewage from any such sewer system into any of the waters of the State, and may stipulate in the permit the conditions on which such discharge may be permitted. Such permit, before being operative, shall be recorded in the office of the Recorder of Deeds for the county wherein the outlet of the said sewer system is located. Every such permit for the discharge of sewage from a sewer system shall be revocable, or subject to modification and change, by the Commissioner of Health, on due notice, after an investigation and hearing, and an opportunity for all interested therein to be heard thereon, being served on the public authorities of the municipality owning, maintaining, or using the sewage system. The length of time, after receipt of the notice, within which the discharge of sewage shall be discontinued may be stated in the permit, but in no case shall it be less than one year or exceed two years, and if the length of time is not specified in the permit it shall be one year. On the expiration of the period of time prescribed, after the service of a notice of revocation, modification, or change, from the Commissioner of Health, the right to discharge sewage into any of the waters of the State shall cease and terminate; and the prohibition of this Act against such discharge shall be in full force, as though no permit had been granted, but a new permit may thereafter again be granted, as hereinbefore provided.

Section 6. It shall be the duty of the public authorities, having by law charge of the sewer system, of every muni-

cipality in the State, from which sewage was being discharged into any of the waters of the State at the time of the passage of this Act, to file with the Commissioner of Health, within four months after the passage of this Act, a report of such sewer system, which shall comprise such facts and information as the Commissioner of Health may require. No sewer system shall be exempt from the provisions of this Act, against the discharge of sewage into the waters of the State, for which a satisfactory report shall not be filed with the Commissioner of Health, in accordance with this section.

SECTION 7. The penalty for the discharge of sewage from any public sewer system into any of the waters of the State, without a duly issued permit, in any case in which a permit is required by this Act, shall be five hundred dollars, and a further penalty of fifty dollars per day for each day the offence is maintained, recoverable by the Commonwealth, at the suit of the Commissioner of Health, as debts of like amount are recoverable by law. The penalty for the discharge of sewage from any public sewer system into any of the waters of the State, without filing a report, in any case in which a report is required to be filed, shall be fifty dollars, recoverable by a like suit.

SECTION 8. All individuals, private corporations, and companies that, at the time of the passage of this Act, are discharging sewage into any of the waters of the State may continue to discharge such sewage, unless, in the opinion of the Commissioner of Health, the discharge of such sewage may become injurious to the public health. If at any time the Commissioner of Health considers that the discharge of such sewage into any of the waters of the State may become injurious to the public health, he may order the discharge of such sewage discontinued.

SECTION 9. Every individual, private corporation, or

company shall discontinue the discharge of sewage into any of the waters of the State, within ten days after having been so ordered by the Commissioner of Health.

SECTION 10. Any individual, private corporation, or company that shall discharge sewage, or permit the same to flow, into the waters of the State, contrary to the provisions of this Act, shall be deemed guilty of a misdemeanor, and shall, upon conviction, be punished by a fine of twenty-five dollars for each offence, and a further fine of five dollars per day for each day the offence is maintained, or by imprisonment not exceeding one month, or both, at the discretion of the Court.

SECTION 11. Any order or decision, under this Act, of the Commissioner of Health, or that of the Governor, Attorney General and Commissioner of Health, shall be subject to an appeal to any Court of Common Pleas of the county wherein the outlet of such sewer or sewer system, otherwise prohibited by this Act, is situated, and said Court shall have power to hear said appeal, and may affirm or set aside said order or decision, or modify the same, or otherwise fix the terms upon which permission shall be granted. But the order or decision appealed from shall not be superseded by the appeal, but shall stand until the order of the Court, as above.

Approved the twenty-second day of April, A. D. 1905.

SAMUEL W. PENNYPACKER.

AN ORDINANCE

To authorize the Department of Public Works to make investigations and report upon a comprehensive plan for the collection, purification and disposal of the sewage of the City, together with such alterations and extensions of the existing sewerage systems as may be necessary, and to make an appropriation therefor.

WHEREAS, By an Act of Assembly of the State of Pennsylvania, entitled "An Act to preserve the purity of the waters of the State for the protection of the public health," approved April 22, 1905, it is provided, among other things, that "No person, corporation or municipality shall place, or permit to be placed or discharge, or permit to flow into any of the waters of the State, any sewage, except as hereinafter provided, etc." Also, that "Whenever it is their unanimous opinion (Governor, Attorney General and Commissioner of Health), that the general interests of the public health would be subserved thereby, the Commissioner of Health may issue a permit for the discharge of sewage for any such sewer system into any of the waters of the State, and may stipulate in the permit the conditions on which such discharge may be permitted," revocable at any time, and

WHEREAS, The Governor of the State, the Attorney General and the Commissioner of Health have by various permits granted the right to the City of Philadelphia to extend various sewer systems, and to discharge the sewage into the waters of the State, subject, among others, to the following condition, "That the City shall, on or before the year one thousand nine hundred and twelve prepare and and submit to the State Department of Health for approval, a comprehensive sewerage plan for the collection and disposal of the sewage of the various drainage districts of the City," and another condition as follows: "Extensions

shall be immediately approved, provided some progress shall be made each year in the study of a comprehensive system of sewerage for the various drainage districts, and provided that said sewer extensions shall not, as far as practicable, be at cross purposes with said comprehensive system," now therefore,

SECTION 1. *The Select and Common Councils of the City of Philadelphia do ordain,* That the Department of Public Works be authorized and directed to make investigations and report upon a comprehensive plan for the collection, purification and disposal of the sewage of the City, together with such alterations and extensions of the existing sewerage system as may be necessary: also to carry on experiments and report upon the feasibility of the treatment of sewage, together with estimates of the probable cost of altering the present sewage systems as far as may be required, of constructing necessary outfall sewers, of constructing disposal works, and the maintenance of the same.

SECTION 2. The Director of the Department of Public Works is hereby authorized to employ in consultation such Engineers and Bacteriologists as may be requisite to reach a satisfactory solution of the problem; and also to employ such engineers and assistants as may be required for making surveys, investigations, experiments and recommendations; all expenses for salaries, inspection, tests, transportation, and incidental expenses, not otherwise provided for, shall be paid out of the appropriation for the work herein authorized.

SECTION 3. The sum of seven thousand five hundred (7,500) dollars is hereby appropriated to the Department of Public Works, Bureau of Surveys, for the work herein authorized.

Approved the twentieth day of July, A. D. 1907.

JOHN E. REYBURN,
Mayor of Philadelphia.

APPENDIX B

TOPOGRAPHY, PRESENT SEWER SYSTEM AND POPULATION STUDIES

Topography

The City of Philadelphia, Pennsylvania, is situated above the confluence of the Schuylkill and Delaware Rivers, the most congested portion lying between the rivers, although closely built areas lie on the banks of the tributaries to both rivers. A considerable portion, about one-third, of the urban section of the city lies west of the Schuylkill River, between it and Cobbs Creek, which forms the westernly boundary line.

The total area of the city is 129.583 square miles, about 60 per cent. of it comprising the areas draining directly into the Delaware River, the remainder into the Schuylkill River and tributaries.

The topography of the city may best be described as rolling. The elevation of the business center of the city around City Hall is from 38 to 40 feet above high tide and from this point eastward, westward and southward, there are gradual slopes toward the rivers. From City Hall northward to Fairmount Avenue, the rise is very slight. In the portion north of Fairmount Avenue, from an elevation of about sixty (60) feet above high tide, the ground rises gradually northward and northwestward to a maximum elevation of 443 feet; in the northeasterly portion of the city there is a high plateau with average eleva-

tion of from 100 to 125 feet above high tide, from which the ground slopes gradually toward the low plain bordering the Delaware River. In the portion of Philadelphia west of the Schuylkill River, the ground is generally high and rolling, rising from the river westward and reaching a maximum elevation of two hundred and ninety-four (294) feet above high tide, with the exception of a considerable area in the southern portion of the Fortieth ward amounting to about 4,000 acres, which would be inundated at every tide if it were not for the protecting dykes. This condition also exists between the rivers in the southerly section below Oregon Avenue.

As the topography has an essential bearing upon the sewer system of a city, it may be stated that the main sewers, for convenience, are designated by the names of the valleys in which they are constructed, or by the streets upon which are their main outfalls. In the Delaware basin, there are such sub-divisions as the Gunners Run, Wingohocking, Cohocksink Creeks, etc., in each of which cases, in place of the original open creeks, there have been built covered conduits or sewers carrying the drainage from the territory tributary thereto.

In the portion of the city west of the Schuylkill River there are such sub-divisions as the Cobbs, Mill and Mantua Creeks, Thomas Run and others, the names for which are purely local.

The Existing Sewer System

The existing sewer system is the result of a growth more or less systematic from a time preceding the year 1855, the year of the consolidation of the various boroughs and townships in Philadelphia County, from which most of the city's records are dated. The mileage of main and branch sewers prior to 1855 and after that in each decade to the present are as follows:

TABLE OF SEWER CONSTRUCTION BY DECADES

	Miles of Sewers	
Period	*Main*	*Branch*
Prior to 1855	18.00	19.50
1855 to 1868	5.20	24.00
1868 to 1874	8.76	57.72
1874 to 1884	14.94	71.56
1884 to 1894	55.70	254.49
1894 to 1904	58.31	302.55
1904 to 1914	34.82	178.86
Total	195.23	908.68

NOTE.—191.8 miles additional not included in table, recently added to the total, consisting of sewers built at private cost and those gathered from all other sources.

The building of sewers in the different boroughs and townships comprising the City of Philadelphia, within the county, was carried on prior to 1855 as the needs arose for carrying drainage from built-up sections into the nearest large streams and for enclosing the channels of streams which intersected them. Between 1855 and 1863 the methods of construction followed precedent. From 1863 to 1876, the Chief Engineer and Surveyor made plans and specifications; from 1877 to 1884, in addition, he controlled the appointment of inspectors, although the work of construction was done by the Department of Highways. After the latter date, the whole responsibility was placed upon the Department of Surveys, which, in 1887, became known as the Bureau of Surveys.

About the year 1878 great improvements were made in principles of design and methods of construction. The principle of preparing plans of the various drainage areas, which naturally divided the city into districts, was established; also the determination of sizes and general alignments of all main and tributary sewers, to which the construction of all sewers was made to conform. In sewer design, provision has been made for main stems and branches pro-

portionate in size and capacity to the work required of them, the coefficient of run-off having been increased to meet modern conditions. In sewer construction, the incorporation of improved materials into the later sewers will add greatly to their length of service.

The percentage of the total mileage of sewers constructed during the last 10, 20 and 30 years may be seen on the following table, rearranged from that preceding:

PERCENTAGE OF TOTAL MILEAGE OF SEWERS BUILT IN LAST 10, 20 AND 30 YEARS

Period	Main Sewers		Branch Sewers	
	Miles	Percentage of total	Miles	Percentage of total
1904 to 1914	34.82	17.8	178.86	19.6
1894 to 1914	93.13	47.7	481.41	53.0
1884 to 1914	148.53	76.0	735.90	81.0

It will be noted from the table that about 20 per cent. of the main and branch sewer system has been built since 1904; that more than 50 per cent. has been built since 1894; and that 80 per cent has been built since 1884; that is, more than three-fourths of the present mileage has been built under the modern design and construction.

The total mileage of sewers built and in operation, together with their cost as of January 1, 1914, is as follows:

TOTAL LENGTH OF SEWERS CONSTRUCTED

	Miles	*Cost*
Main Sewers	195.23	$16,151,183.68
Branch Sewers	908.68	15,434,158.39
Private sewers (estimated—not recorded)	158.309	2,507,614.56
Miscellaneous sewers*	23.48	1,209,631.75
	1,285.699	$35,302,588.38

* As of January 1, 1912.

As a result of the surveys of the older main sewers made in 1910 and mentioned in this report reconstruction is recommended as follows:

Name of Sewer	Miles Examined	Location of Recommended Reconstruction	Estimated Cost
Cohocksink System	1.08	In Thompson street, from Randolph street to Fifteenth street	$150,000
Christian Street System	1.61	Delaware River to Thirteenth street, and in Thirteenth street, Christian street to South street	250,000
Passyunk Avenue	0.29	Christian street to Ellsworth street	20,000
Aramingo System	0.88	In Huntingdon, Sergeant, Amber and Coral streets	70,000
York Street	0.63	Emerald street to American street	81,000
Cohocksink	0.60	Allen street to Van Horn street	30,000
Cohocksink System	0.53	In Masher, Oxford and Howard streets	28,000
Cohocksink System	1.08	In Hancock, Laurel, Bodine and Culvert streets	65,000
Cohocksink System	0.53	Randolph street, Oxford street to Montgomery avenue	70,000
Cohocksink System	0.70	In Eighteenth street, and in Berks street from Eighteenth to Twenty-first streets	22,000
Cohocksink System	0.16	In Wildey street and Second street	25,000
Mill Creek System	0.72	In Forty-sixth street, Sansom street to Pine street	10,000
Larchwood Avenue	0.91	Schuylkill River to Thirty-first Street	65,000
Thirteenth Street	1.34	Lombard street to Pine street	9,500
Dock Street	0.35	Delaware River to Third street	20,000
Nineteenth Street	0.38	Federal street to Catharine street	20,000
Fairmount Avenue	1.72	Delaware River to Fifth street	105,000
Ellsworth Street System	1.13	In Twenty-fifth street, Federal to Ellsworth street	22,000
Mantua Creek System	0.28	In Thirty-eighth street, Brown street to Wallace street	34,000
			$1,096,500
For alterations to present sewer outlets in conformity to the proposed plan			263,500
			$1,360,000

NOTE:—The above does not include the reconstruction and repairs to the Cohocksink System required by examinations made prior to 1910.

Types of Construction

The older sewers, from 40 to 80 years ago, were built of brick and lime mortar. In some cases the bottoms were laid without mortar joints, as the theory at that time was that sewers laid in that way would serve to extract the subsurface water from the soil and carry it through these channels to the rivers. It was not the practice at that time to connect water-closets with sewers. Later, this method of sewer construction was abandoned. When hydraulic cement came into use it was substituted for lime, and its use has added greatly to the life of the sewers.

Twenty-five years ago, the construction of vitrified clay pipe sewer was introduced; the improvements in the manufacture of this class of material have favored its continuance and it is used largely. The development of the different uses of concrete has resulted of late years in the building of a number of large sewers of concrete reinforced with steel. The latter is the newest type of sewer construction and is used wherever conditions are suitable.

Methods of Collection and Disposal

In the earlier days of the city, sewers were constructed from the villages to the nearest large stream and the sewage allowed to run directly into it. As the population and hence the amount of sewage introduced into these streams have increased, they have become foul and objectionable to the adjacent residents. With the expansion of the city, these streams have largely been directed into main sewers which carry the drainage to outfalls, at the banks of the rivers.

During the past few years, collectors have been built along a number of creeks, to gather the dry weather flow and first flush of rainfall from the combined sewers and to carry them to points more remote from population, which sewers will be extended to disposal works to conform with the comprehensive plan.

In the earlier days, the streets of the city were paved generally with cobble stones. Within the last twenty-five years, these cobble stones have given place to more modern materials: granite block, vitrified brick and block, asphalt and granoithic pavement. The streets as originally paved did not readily permit the storm water to be carried off, but allowed a large percentage of the rainfall to percolate through the soil. The laying of an increasing number of improved pavements, however, and the paving of large yard areas with impermeable materials have given rise to a new condition, resulting in the rapid run-off of the storm water and allowing it to reach the sewers in shorter time and in greater volume than was the case under the old conditions, causing congestion in the old sewers and requiring the building of relief sewers to carry it off without damage to property.

The increase in the number of miles of impermeable pavement has also shown the inadequacy of the number of inlets that were sufficient under the old conditions; it is therefore necessary to continue the construction annually of a large number of inlets, in order that water may be carried more quickly into underground channels, thence to the rivers.

POPULATION STUDIES

The economic period for study of the collecting sewers and design of the treatment works having been arbitrarily determined as the year 1950, it then became necessary to estimate the total population of Philadelphia for that year and a rate of growth of population in order to design works to be built in progressive steps to meet the conditions at each successive date. Census returns for Philadelphia are available from 1790 to 1910 inclusive, and based upon these it is estimated that the total population of Philadelphia in 1950 will be 3,090,000.

There are certain natural drainage areas of Philadelphia which extend into the adjoining counties and, anticipating the extension of the present political boundaries of the city to include parts of these areas, the total population tributary to the recommended sewage treatment works is estimated at 3,151,000.

Prior to the design of the water filtration plants of Philadelphia, a study was made of the probable future population of the City of Philadelphia, and the Transit Commissioner, in his investigations, made similar estimates. The former studies were made about 1904 and the latter in 1912.

Shortly after the 1910 census the Bureau of Surveys made investigations of the distribution of the population as of that census and estimated future populations.

The studies for the improvement of the water supply, of the Transit Commissioner and of the Bureau of Surveys for Sewage Disposal are as follows:

Year	Water	Transit	Sewage Disposal
1900	1,293,700	1,293,700	—
1910	1,583,900	1,549,000	1,549,000
1920	1,930,700	1,825,000	1,900,000
1930	2,344,300	2,108,000	2,280,000
1940	2,835,300	2,391,000	2,690,000
1950	3,479,200	2,669,000	3,090,000
1960	—	2,936,000	—

For the purpose of sewage disposal investigations it was necessary not only to estimate the total future population of the city, but also to obtain a knowledge of its probable distribution over the area of the city, in order to intelligently design the collecting system of sewers.

This was done by dividing the city into areas representing the original 24 wards created in 1854 at the consolidation of the city. Using the census returns, 1860-1910,

for these areas (represented by the sum of their subdivisions at each decade), a curve was platted for each of them and projected forward to 1950. The projected curves were then adjusted so that the summation of the 1950 populations equaled the estimated population of the entire city.

The census returns of 1910 and estimated population in 1950 are given as follows for the original 24 wards:

Original Wards	Present Wards	Census, 1910	Estimates, 1950
1	1, 39, 26, 36, 30	247,535	548,800
2	2	40,536	45,000
3	3	25,747	31,000
4	4	22,316	22,000
5	5	17,000	17,000
6	6	6,374	6,100
7	7	27,425	27,500
8	8	13,965	14,000
9	9	5,071	5,000
10	10	19,426	19,500
11	11	11,619	11,500
12	12	15,152	15,000
13	13	19,769	20,000
14	14	19,477	19,500
15	15	47,273	50,000
16	16	16,175	16,000
17	17	17,484	17,500
18, 19, 23	18, 19, 31, 23, 35 41, 25, 45, 33, 43	332,310	681,000
20	20, 29, 47	105,575	114,000
21	21, 28, 38, 37, 32	196,990	380,000
22	22, 42	93,855	419,000
24	24, 34, 44, 27, 46, 40	247,928	615,500
		1,549,008	3,090,000

It will be noted that wards 2 to 17 inclusive show no increase between 1910 and 1950, and also that they are today the same areas as in 1854.

Next it was necessary to sub-divide the other original wards.

The dates of the creation of each of the present forty-seven wards were found from the Court records and are shown in the 1912 Annual Report of the Bureau of Surveys.

In order to explain how the sub-divisions were made the original First ward is given as an example:

SUB-DIVISIONS OF THE ORIGINAL FIRST WARD

1854	1864	1875	1892	1898	1910
1	1	1	1	1	1
				39	39
	2	26	26	26	26
			36	36	36
		30	30	30	30

This table shows that in 1864 the original First ward was sub-divided into two parts, called at that time the First and Twenty-sixth wards; that in 1875, the then Twenty-sixth ward was sub-divided into two parts, one called the Twenty-sixth and the other the present Thirtieth ward; that in 1892, the then Twenty-sixth ward was divided into the present Twenty-sixth and Thirty-sixth wards; and that in 1898, the then First ward was divided into the present First and Thirty-ninth wards.

The original First ward was then divided into two geographical areas composed of the present First and Thirty-ninth wards, and of the present Twenty-sixth, Thirty-sixth and Thirtieth wards, and the population of these areas was platted for censuses of 1870, 1880, 1890, 1900 and 1910.

Projecting the curves and adjusting the 1950 points so that their sum equals 548,000, the already determined figure for the original First ward, the population in the present First and Thirty-ninth wards is estimated to be 215,000 in 1950, and in the present Twenty-sixth, Thirty-sixth and Thirtieth wards, 333,000.

The 215,000 for the First and Thirty-ninth wards is then sub-divided by platting the present First and Thirty-ninth

wards for 1900 and 1910. As the First ward is solidly developed and the Thirty-ninth rapidly growing the curves are quite different, and it is found that the First ward in 1950 should contain 50,000 persons and the Thirty-ninth, 165,000.

The area represented by the present Twenty-sixth, Thirty-sixth and Thirtieth wards was similarly divided.

In projecting forward all wards of which only one or two census figures were available, a study was made of the atlas to see how the ward could develop before the curve was assumed.

In this way an estimated population for the year 1950 was obtained for each of the present 47 wards, shown in the 1912 Annual Report of the Bureau of Surveys.

A map of the city was prepared showing each drainage area, ward boundaries and the census enumeration districts. From this the population on the drainage areas in 1910 was obtained directly and the anticipated population in 1950 estimated.

The entire city was then divided into the three divisions called Northeast, Southwest and Southeast.

The 1910 population on each of these three major divisions was determined by using the sum of the populations in wards wholly within the area under consideration and by subdividing the population in wards which overlapped. This latter was done by means of the small census enumeration districts and the atlas.

The estimated 1950 population was similarly determined and results are as follows:

	1910	*Estimated, 1950*
Northeast	342,000	1,100,000
Southwest	940,000	1,663,000
Southeast	267,000	390,000

Each of these major divisions was then sub-divided into populations tributary to the collectors and again subdivided into areas tributary to each main sewer above its point of interception.

APPENDIX C

SEWERAGE WORKS ALREADY CONSTRUCTED FOR THE COLLECTION AND TREATMENT OF SEWAGE IN PHILADELPHIA

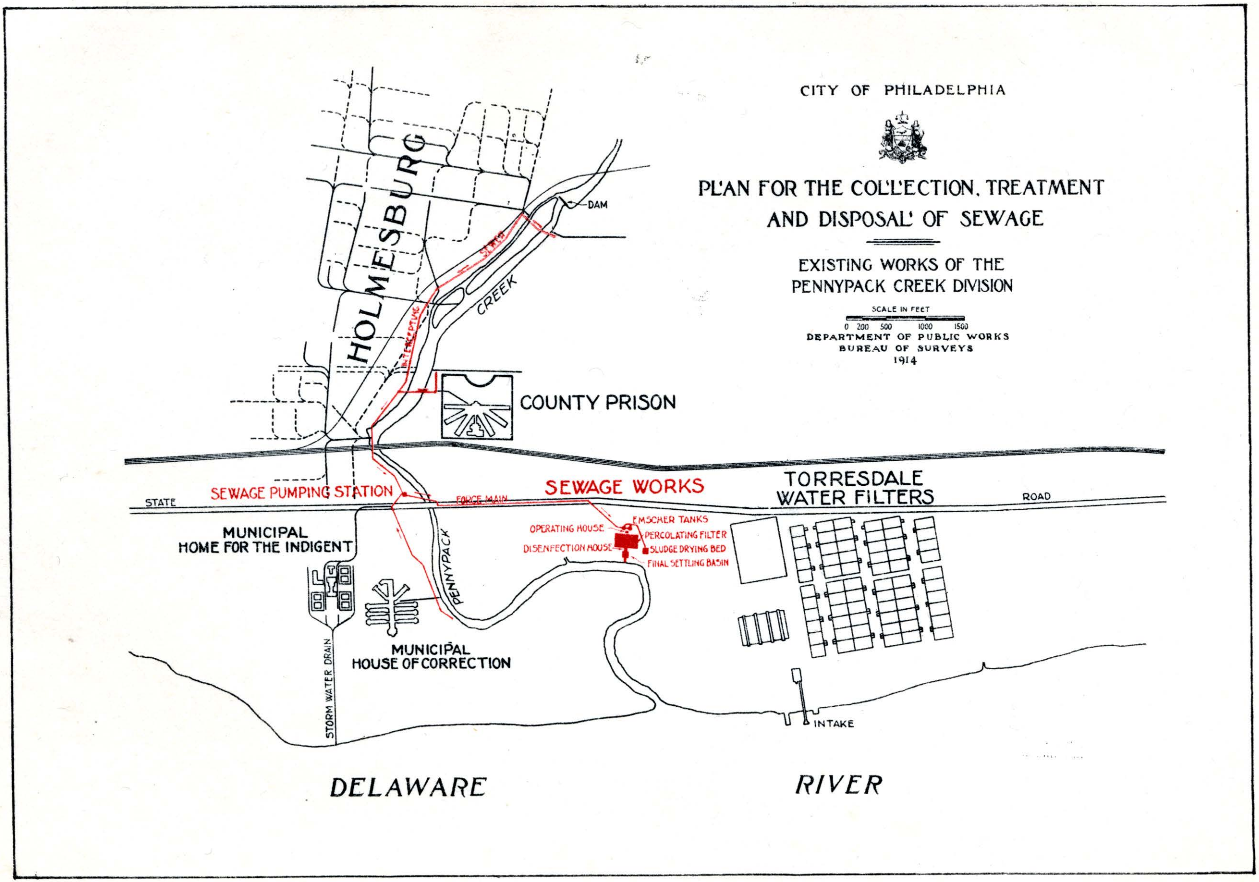
The first municipal water supply of Philadelphia was put in service in 1801. The water of the Schuylkill River was admitted to small basins at the foot of Chestnut Street, lifted to a conduit which carried it to Center Square (now the site of the City Hall), where it was again pumped to a small storage tank and distributed through bored logs to the citizens.

At that time, the population of the city was small and the buildings lay principally between Vine and South Streets and between the Delaware and Schuylkill Rivers. Few towns existed on the banks of the latter river and its water was almost uncontaminated by sewage, mine wastes or other impurities.

As the town grew, the outlying townships installed their own water supplies, all of which were obtained from the Schuylkill River, except Kensington, which used the Delaware.

As these two rivers have, from the beginning, formed the source of water supply and also are the natural drainage courses for the city, it is but natural to find that the problems of sewage collection and water supply are intimately related in Philadelphia.

In 1844, largely at the instigation of the College of Physicians, the city purchased a tract of land on the east bank of the Schuylkill above Fairmount Dam now known as



CITY OF PHILADELPHIA
PLAN FOR THE COLLECTION, TREATMENT AND DISPOSAL OF SEWAGE
EXISTING WORKS OF THE PENNYPACK CREEK DIVISION
SCALE IN FEET
0 200 500 1000 1500
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
1914
HOLMESBURG
DAM
CREEK
INTERCEPTING
COUNTY PRISON
TORRESDALE
WATER FILTERS
SEWAGE WORKS
SEWAGE PUMPING STATION
FORCE MAIN
STATE
ROAD
MUNICIPAL
HOME FOR THE INDIGENT
EMSCHER TANKS
OPERATING HOUSE
PERCOLATING FILTER
DISENFECTION HOUSE
SLUDGE DRYING BED
FINAL SETTLING BASIN
PENNYPACK
MUNICIPAL
HOUSE OF CORRECTION
STORM WATER DRAIN
INTAKE
DELAWARE
RIVER

Pumping Station, Pennypack Creek Works, Philadelphia.

Lemon Hill, in order to protect Fairmount pool from sewage pollution.

The Act of Assembly of March 26, 1867, creating Fairmount Park, stated that the land taken was to be "an open public place and park for the health and enjoyment of the people of said City and the preservation of the purity of the water supply of the City of Philadelphia." Under this Act, 3,448 acres of land are now embraced in park property along the banks of the Schuylkill River, Wissahickon Creek and their tributaries. The funds invested therein may be considered as expended toward the same purpose as the works recommended for the collection and treatment of the sewage inasmuch as they both are to protect the purity of the source of the city's water supply.

In 1882, surveys and plans were made, and in 1883, construction begun on the intercepting sewer which extends from below Fairmount Dam along the east bank of the Schuylkill nearly to county line. Branches were built along the Wissahickon Creek with spurs up Monoshone and Cresheim Creeks and the separate system of sewers rapidly installed over the tributary drainage areas.

These intercepting sewers (excluding the separate system of sewers needed to drain the properties) represents an expenditure of about $1,000,000 by the City of Philadelphia for the collection of sewage as a protection of the source of the water supply and the maintenance of the rivers and creeks flowing through park property in a clean condition for the pleasure of the citizens.

This system of sewers and main interceptors complete will be utilized in the plan recommended, the only addition needed being the extension of the main interceptor from Fairmount dam to the proposed Callowhill Street pumping station, where the sewage will be lifted into the main gravity collector for the Southwest Division and be carried to the Southwest Works for treatment.

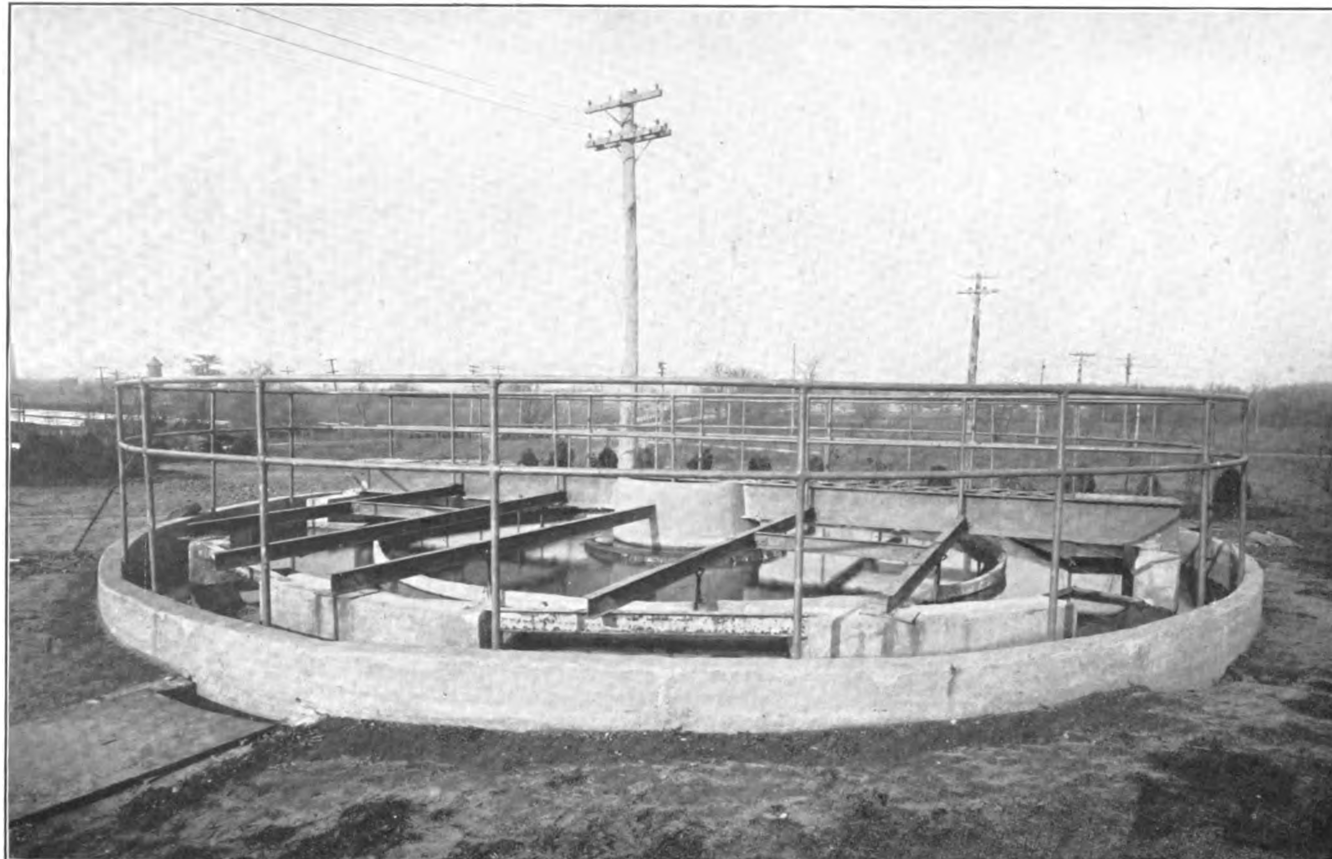
As West Philadelphia developed, sewers were built for the territory included in the watershed of Cobbs Creek. The drainage from the adjoining county likewise was carried to the creek, so that it became seriously polluted by sewage. In 1907 the city began the construction of a collector along the east bank of the creek from the tide-water at Grays Avenue. This collector has been extended from year to year until it now has reached Sixty-eighth and Race Streets, a point about 5 miles from the outlet, and, as has been described, keeps out of Cobbs Creek most of the sewage contributed from Philadelphia County. This collector represents an investment of $327,000, and also will be wholly utilized by the recommended plan.

The next expenditure of funds toward the solution of tne problem of sewage disposal for Philadelphia was in the operation of an experiment station during 1909 and 1910.

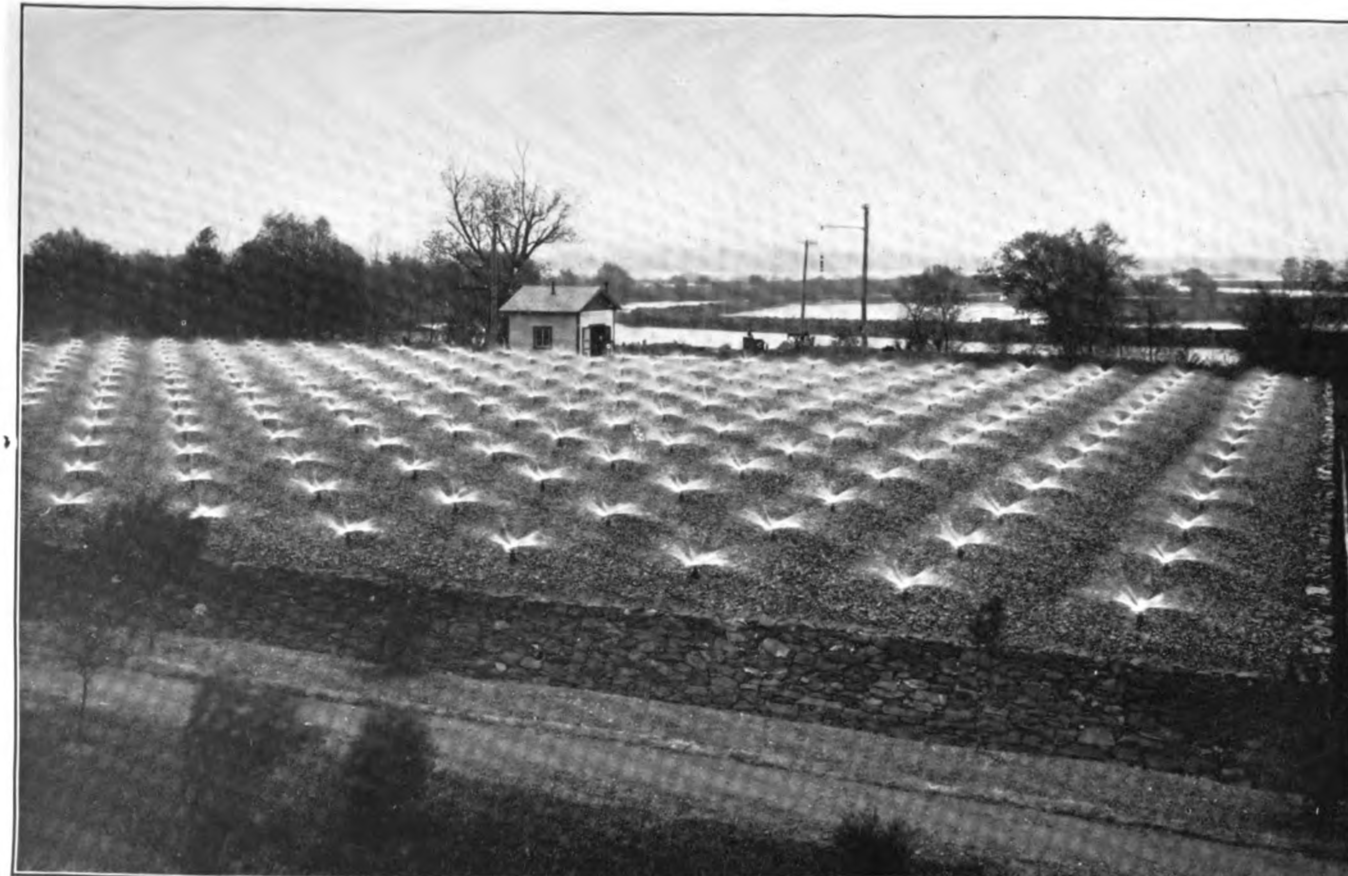
The testing station near the Spring Garden Pumping Station, used in investigating the methods of water purification prior to the improvement of the water supply, was remodeled and adapted for experimental sewage treatment purposes. All the available processes were tried out on a characteristic sewage, many improvements made in the art of sewage treatment and many valuable data obtained for the design of the proposed treatment works for the city. A comprehensive report of the operation of this testing station was prepared and published in 1911. The expenditures for these experiments by the Bureau of Surveys amounted to about $25,000. Valuable assistance in men and materials was furnished by the Bureau of Water.

Another progressive step toward the plan for protecting the water supply of the city and restoring a polluted creek to a clean condition was in the construction of the Pennypack Creek Sewage Disposal Works.

As shown on the plan, Pennypack Creek enters the Delaware River about 2,000 feet from the intake of the



Emscher Tank, Pennypack Creek Works, Philadelphia.



Percolating Filter, Pennypack Creek Works, Philadelphia.

Torresdale water filters. Upon the watershed of the creek are located three municipal institutions and the village of Holmesburg, the drainage from which formerly was discharged into the creek causing a serious pollution which reached the water supply intake.

In 1910 the construction of collectors was begun along the banks of the creek to gather the sewage and convey it to a pumping station near State Road. Here the sewage is passed through a grit chamber and coarse screens and forced to the treatment works which are located east of State Road and Ashburner Street.

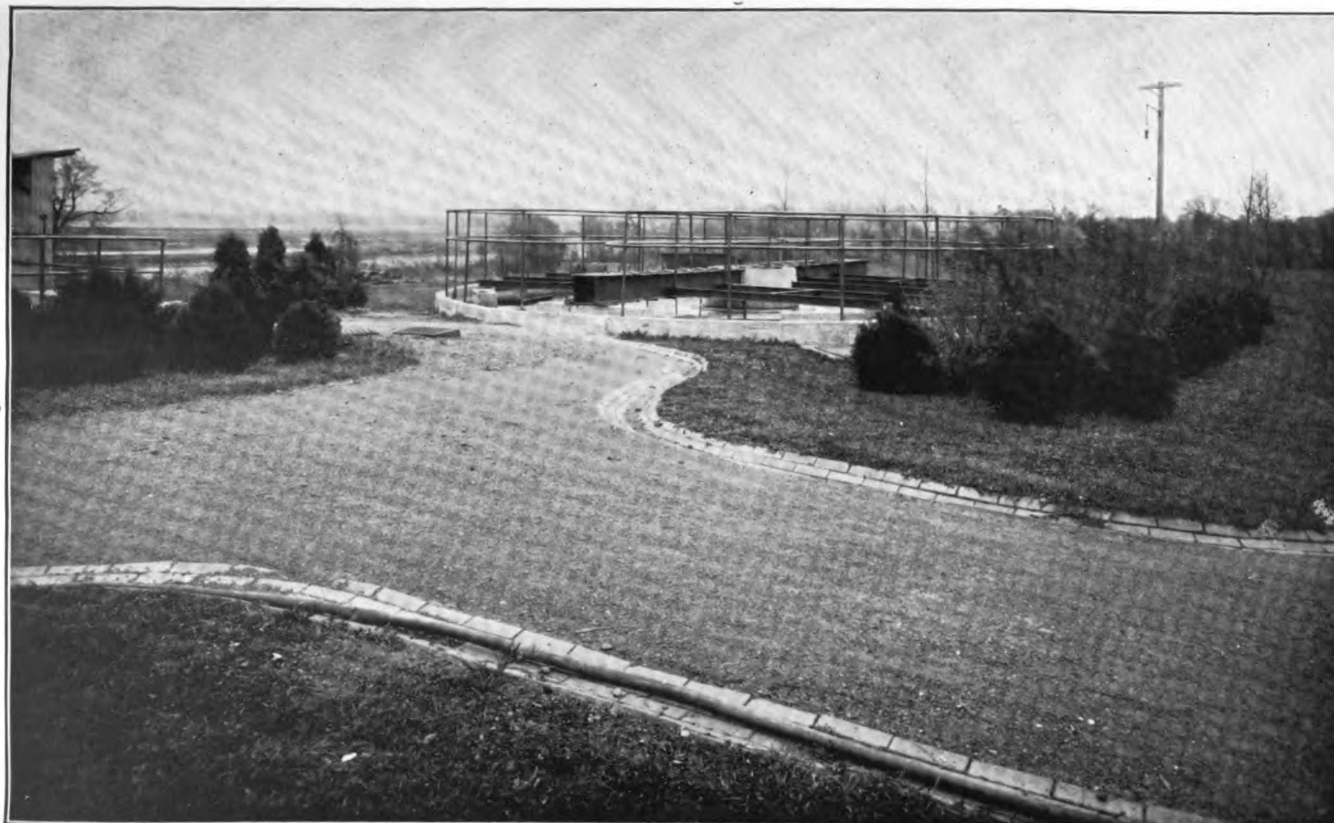
The design of these works was based upon the best practice of America, Germany and England, with many improvements and devices found experimentally successful in the testing station and introduced in these works in order to determine their fitness under actual working conditions for inclusion in the plans for the large treatment works for the whole city.

The sewage is first passed through two sedimentation tanks of the Emscher type in order to remove the settleable matter; it is then sprayed over a one acre percolating filter to oxidize the putrescent matters; disinfected with a solution of hypochlorite of calcium to destroy the disease germs; and finally settled in order to remove any suspended matter which may have passed through prior processes.

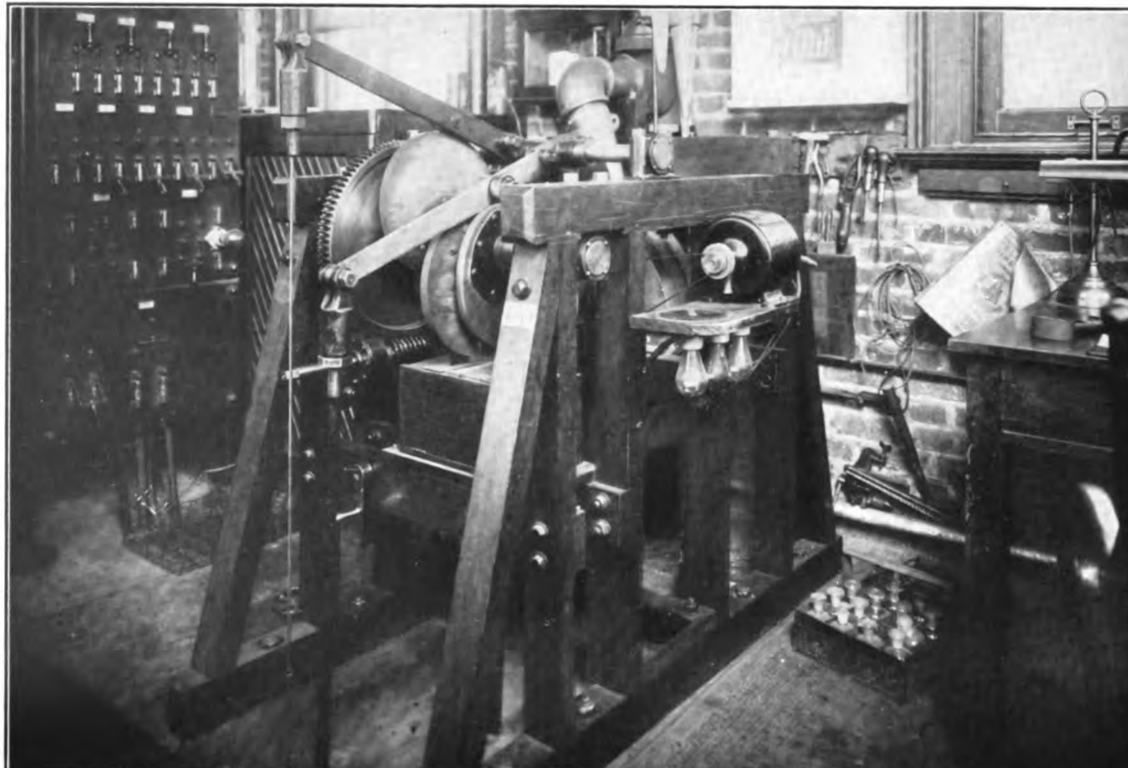
The plant has been successful in producing an effluent free from suspended matter and disease germs and which will not putrify. This has been accomplished without the production of bad odors or offense of any kind. The grounds are parked with trees, shrubs, flower-beds and well kept lawns, so that they present an attractive appearance. There is no reason why the large plants cannot be made equally attractive by similar parking.

The collectors, pumping station, treatment works and appurtenant parts represent an investment by the city of

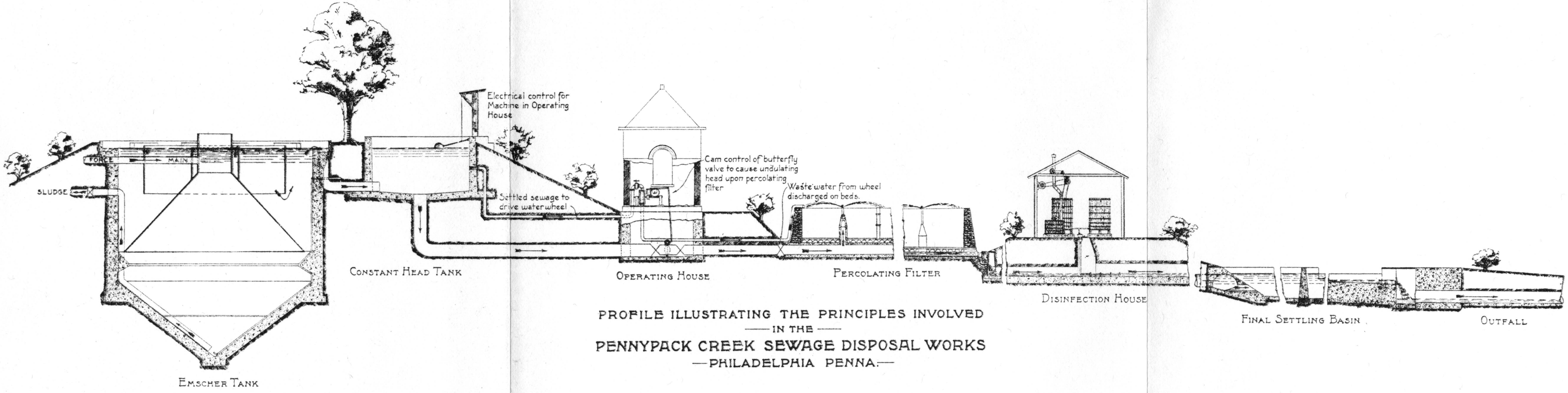
$193,000. The collectors and pumping station after enlargement will be utilized in the plan recommended for the disposal of the sewage of the entire city. The treatment works will afford protection from sewage pollution of the Pennypack Creek drainage area to the source of the water supply until the upper Delaware collector is constructed to carry the sewage to the proposed Northeast Treatment Works, and until this time, it is intended to try out experimentally at the works, possible improvements in the treatment processes to aid in the design of the larger works.



Emscher Tank, Pennypack Creek Works, Philadelphia.



Distribution Control Machine, Pennypack Creek Works, Philadelphia.



PROFILE ILLUSTRATING THE PRINCIPLES INVOLVED
—IN THE—
PENNYPACK CREEK SEWAGE DISPOSAL WORKS
—PHILADELPHIA PENNA.—

SANITARY EXAMINATIONS OF THE DELAWARE AND SCHUYLKILL RIVERS AT PHILADELPHIA

	Location	Date	Parts per Million														Bacteria per C. C.		Location
			Total Residue			Turbidity	Nitrogen as					Oxygen Consumed		Chlorine	Dissolved Oxygen		Gelatine 48 hrs. @ 20° C.	B. Coli†	
			Total	Fixed	Volatile		Organic	Albuminoid Ammonia	Free Ammonia	Nitrites	Nitrates	5 min.*	30 min.*		P. P. M.	Per cent. Sat.			
Schuylkill River	Falls Bridge	Mar. 30-10	179	—	—	9	—	.124	.044	.036	.87	4.0	4.8	7	9.8	97	210,000 176,000 178,000	10 10 10	East Bank Mid Stream West Bank
	Girard Avenue	Mar. 30-10	165	—	—	9	—	.112	.060	.036	.87	2.8	5.2	7	9.8	96	15,500 21,000 33,000	5 10 5	East Bank Mid Stream West Bank
	Market Street	Apr. 4-10	210	120	90	26	1.366	.44	.314	.040	.48	4.4	5.2	11	8.1	80	220,000	—	Composite Sample
	Gray's Ferry	Apr. 4-10	220	132	88	27	1.33	.36	.570	.040	.60	3.2	5.6	13	1.6	16	1,000,000	1,000,000	Composite Sample
	Passyunk Avenue	Apr. 4-10	732	316	416	25	1.282	.33	.568	.080	.52	6.4	5.6	13	2.1	21	785,000	?	Composite Sample
	Penrose Ferry	Apr. 4-10	412	324	88	105	1.65	.24	.750	.090	.48	11.2	15.2	15	0.6	6.3	775,000	100,000	Composite Sample
Delaware River	Torresdale	Apr. 11-10	90	58	32	11	.32	.13	Trace	.001	.36	2.9	8.8	2.7	10.5	94.5	1,050 1,150 1,800	10 10 1	West Bank Mid Stream East Bank
	Bridge Street	Apr. 11-10	66	32	34	22	.25	.19	.13	.005	.36	3.9	8.8	3.5	8.5	80.5	68,000 18,500 17,400	100 100 100	West Bank Mid Stream East Bank
	Tioga Street	Apr. 11-10	92	60	32	28	.32	.23	.30	.009	.30	4.5	8.8	5.5	6.4	61	62,000 46,000 32,000	100 100 100	West Bank Mid Stream East Bank
	Christian Street	Apr. 14-10	112	80	32	36	.83	.23	.23	.016	.56	4.5	8.4	6.0	6.5	60	48,500 56,500 50,000	100 100 100	West Bank Mid Stream East Bank
	Point House	Apr. 14-10	96	66	30	32	.80	.26	.24	.014	.40	4.3	8.0	5.5	6.4	59	100,000 61,500 16,500	100 100 100	West Bank Mid Stream East Bank
	Fort Mifflin	Apr. 14-10	124	30	94	40	.85	.23	.33	.018	.52	5.2	8.4	5.7	5.7	53	115,000 40,000 30,000	100 100 10	West Bank Mid Stream East Bank

* NOTE.—Under Oxygen Consumed 5 min. indicates 5 min. boil; while 30 min. indicates 30 min. on bath at 100° C.

† NOTE.—Tests for B. Coli are presumptive tests only. No confirmative tests carried out.

APPENDIX D

SANITARY SURVEYS OF THE DELAWARE AND SCHUYLKILL RIVERS AT PHILADELPHIA

During the operation of the sewage testing station in 1910, complete chemical analyses of the water of the two rivers were made. Each sample analyzed was composed of from 12 to 18 separate samples collected near the bottom, midway and near the surface of the river. The quantity of each of the separate samples used to make up the large sample was determined by the discharge of the river at the point of collection as measured by a current meter. In this way the composite sample analyzed truly represented the quality of water at the cross section under observation. The table containing the analyses of the water of the Schuylkill River collected at Falls Bridge and Girard Avenue shows by comparison with the analyses of those collected at Market Street, Grays Ferry, Passyunk Avenue and Penrose Ferry the protection against sewage pollution from Philadelphia afforded by the intercepting sewer, and also the progressive pollution of the water of the Schuylkill River below Fairmount Dam. The analyses of the water of the Delaware River show at Torresdale the quality of water used as a source of the city's water supply, and as all of the samples were taken on the ebbing tide, the progressive pollution of the river as it flows from Torresdale to Fort Mifflin is clearly seen.

DELAWARE RIVER, 1912

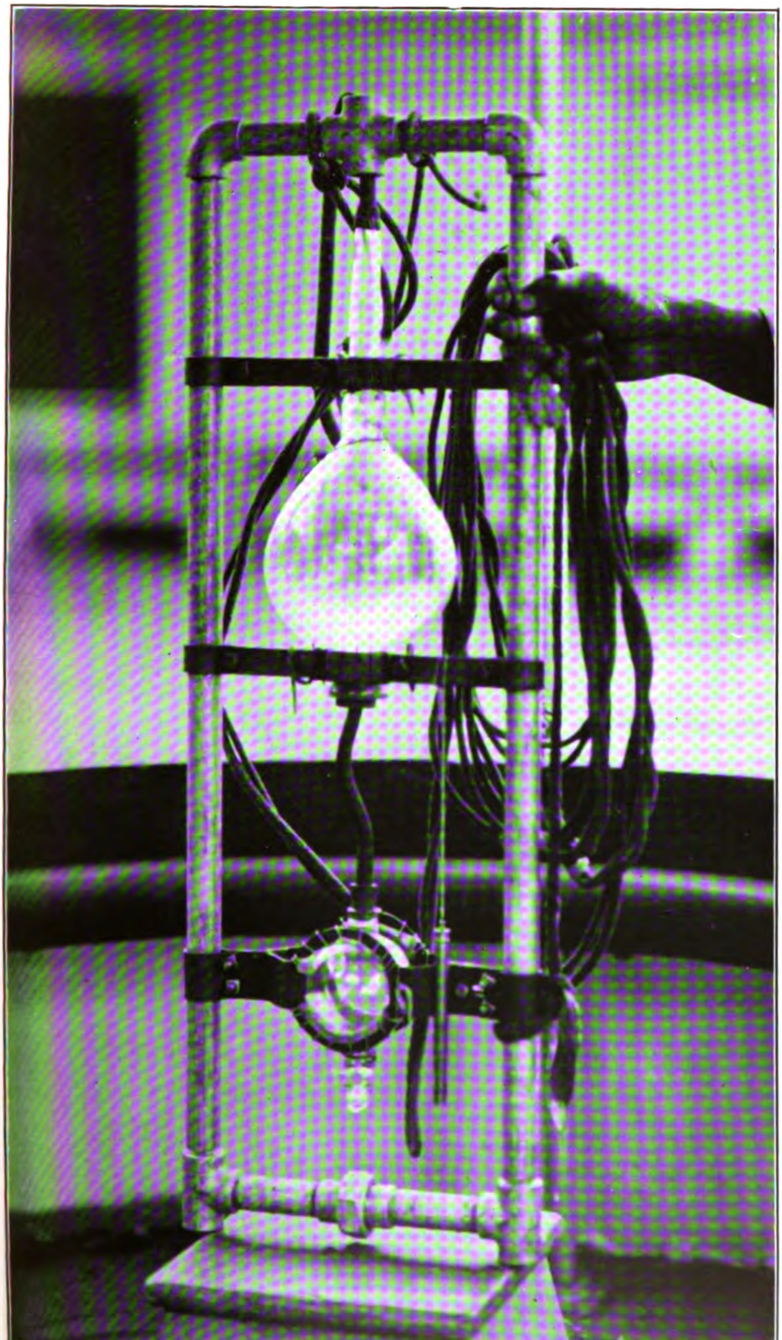
Cross Sections

At Arch Street

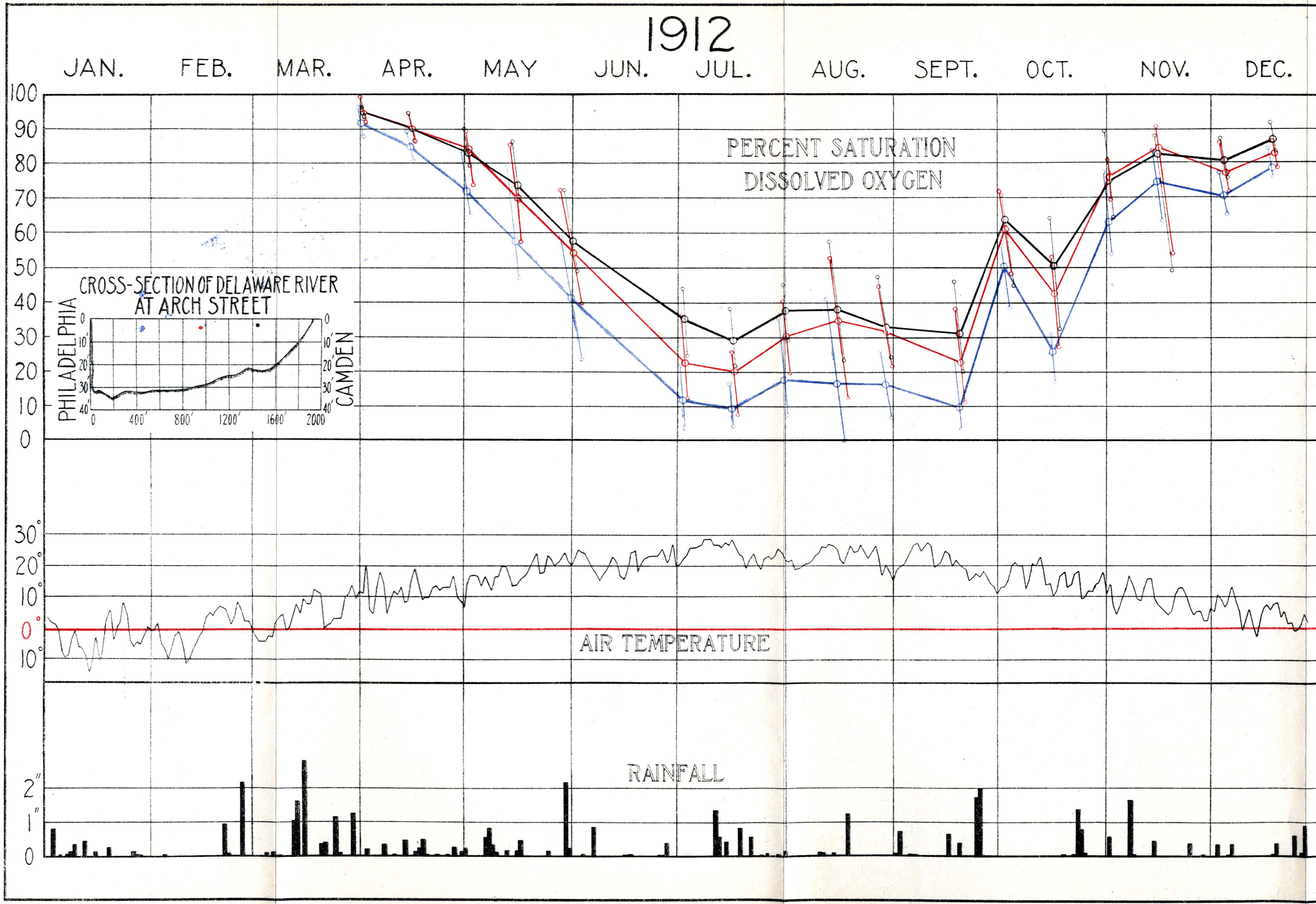
Beginning in 1912, the water of the Delaware River was examined to determine the seasonal and tidal variations in the quality of the water, as determined by its percentage of saturation with dissolved oxygen. The former was determined by selecting a cross section of the river at Arch Street. This point is in front of the business portion of the city and there are no sewers with large drainage areas emptying into the river in the immediate vicinity. Samples of the water were taken at 15 minute intervals, 2 to 3 feet beneath the surface, at three points in the cross section.

The apparatus used in collecting samples during 1914 is shown in the accompanying illustration. This proved more reliable than the usual form, where the large container is placed beside the sample bottle. When the apparatus reached the surface the rubber tube was pinched, preventing return of water into the lower separatory funnel, and when it could be reached the lower stop cock closed. The thermometer was kept in the large separatory funnel.

In the diagram the large circle indicates the average result of one day's observations at each of the sampling points and the small circles connected by the inclined line indicate respectively the maximun and minimum conditions observed at that point on the day in question. Considering the annual curve shown on the diagram, it will be seen that as the temperature rose during the spring, the biological forces of the river became more active and drew heavily upon the oxygen in the water in order to accomplish the oxidation of the sewage. During July, August and September, with no excessive storms, the oxygen content of the river was uniformly low, especially on the west or Philadelphia side of the river. However, during those months there was no



Apparatus used for Collecting Samples of River Water for the Dissolved Oxygen test.



CITY OF PHILADELPHIA

PLAN FOR THE COLLECTION, TREATMENT AND DISPOSAL OF SEWAGE

SANITARY SURVEYS OF THE RIVERS
SEASONAL EFFECT UPON DISSOLVED OXYGEN

DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
1914

LEGEND

- EAST SAMPLING STATION BLACK.
- MID STREAM SAMPLING STATION RED.
- WEST SAMPLING STATION BLUE.

MAXIMUM
AVERAGE DAYS OBSERVATIONS
MINIMUM

nuisance to smell from the river water, notwithstanding the fact that on the Philadelphia side the water on an average never contained 20 per cent. of its completely saturated amount of dissolved oxygen and single samples were frequently below ten per cent. saturation.

The intimate relation between temperature, rainfall and the amount of dissolved oxygen in the water is clearly shown by the examinations made between the middle of September and the middle of October. It will be noted on the diagram that there was a steady fall of temperature from the middle of September to the first of October, that during the same period there were four rain-storms, two of which were prior to the first examination of the river in October.

The result of this fall in temperature and rain storms was to raise the dissolved oxygen content of the west or Philadelphia sampling station from 10 per cent. to 50 per cent. It will also be noted that before the next observation, about the middle of October, the temperature rose and there was no rainfall and the dissolved oxygen content of the water fell back to a position that appears to be the general trend of the seasonal curve.

At Torresdale Intake Section

On September 5, 1912, an all-day observation was made in the cross section of the Delaware River in front of the intake to the Torresdale water filters. The results are shown on the diagram, and it will be seen by comparison with the quality of water at Arch Street on the same date as shown on the diagram of seasonal effect the freedom of the water at the Torresdale intake from serious pollution from the sewage of Philadelphia carried up by the flood tide. The uniform quality of the water at the three sampling stations can be seen by the closeness of the three lines on the diagrams. The tidal influence is also seen, the end

of the ebb tide representing the best up-stream water and the end of the flood tide representing the worst water which reached the Torresdale intake from below.

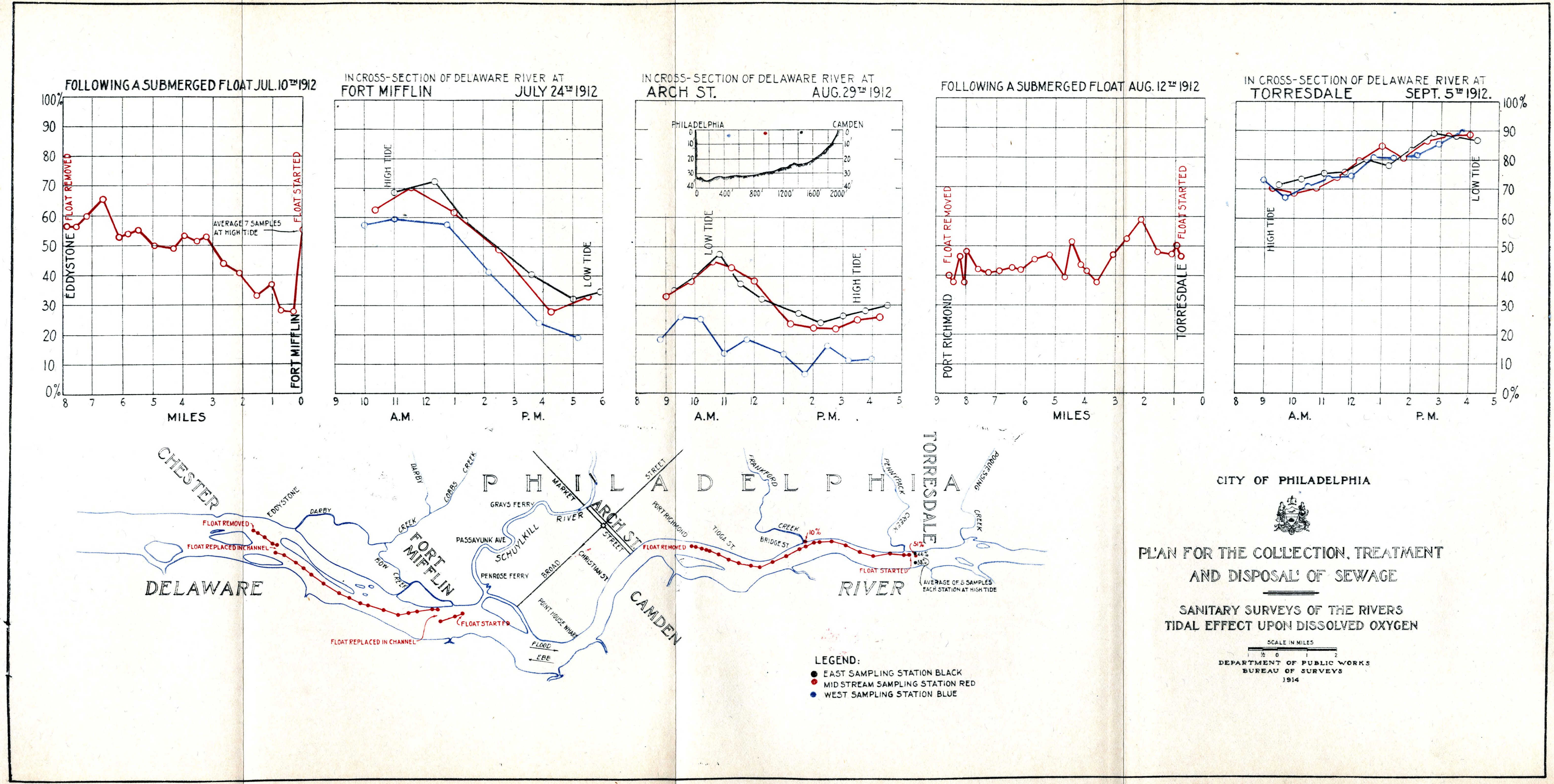
At Fort Mifflin

On July 24, 1912, an all-day observation was made of the river in a cross section at Fort Mifflin, this being below the mouth of the Schuylkill River; it is a point where the river carries the entire sewage of Philadelphia and the other cities and towns upon their water-sheds. The tidal influence at this point is marked; the water on the flood tide is water which formerly oscillated before the city and in which the natural and biological forces of the river have been at work for some time. The water at the end of the ebb tide, however, is water upon which these forces have acted a shorter time and consequently the sewage matters are drawing more heavily upon the oxygen of the water. In addition to the depletion of oxygen as shown at this cross section by biological forces, it must also be borne in mind that the water flowing from the Schuylkill River into the Delaware River as the tide ebbs is almost completely exhausted of dissolved oxygen, and this mechanically causes a lowering of the dissolved oxygen in this cross section.

At Chester

On August 6, 1912, an examination of the water of the Delaware River in front of Chester was made. Twenty-four samples were taken, including the ebb and the beginning of the flood tides, which would represent the water most influenced by the sewage of the City of Philadelphia. There was very little difference among the samples, their average being about 70 per cent. saturation.

It is of interest to compare the condition of the river at Arch Street and at Chester, as shown by this examination and the curve on the diagram entitled "Seasonal Effects."



CITY OF PHILADELPHIA

PLAN FOR THE COLLECTION, TREATMENT AND DISPOSAL OF SEWAGE

SANITARY SURVEYS OF THE RIVERS
TIDAL EFFECT UPON DISSOLVED OXYGEN

DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
1914

The water at Arch Street contains sewage but recently added from the sewer outlets and with a high avidity for oxygen. The water at Chester contains sewage matters from Philadelphia which have been carried back and forth by the rising and falling tide, and therefore subjected to the biological forces of the river, so that a very considerable oxidation has occurred and the recovery of dissolved oxygen by absorption from the air, from green plants and fresh water added to the river, is evidence of the amount of work accomplished by the river towards the ultimate purification of the sewage discharged into it.

Float Observations

From Torresdale to Port Richmond with the Ebbing Tide

On August 21, 1912, a submerged float was followed with the ebbing tide from the Torresdale intake to below Port Richmond. The results of this observation are shown on the diagram, wherein it will be seen that there was but little deterioration in the quality of the water as it flowed past the upper portion of the city.

From Fort Mifflin to Eddystone with the Ebbing Tide

On July 10, 1912, a submerge float was followed on the ebbing tide from Fort Mifflin to Eddystone; results are shown on the diagram.

In considering the Fort Mifflin Section it has been shown how the water at the end of the flood tide is of better quality than during the ebbing tide. It was observed that at the end of the flood tide in the Delaware River, the water of the Schuylkill River began to flow out and mingle with the rising tide in the Delaware River. This will explain the sudden drop in dissolved oxygen from 55½ per cent., representing the end of the flood tide in the Delaware River, to 27.6 per cent. a short time afterward, when the water of the Schuylkill River had flowed out into the channel of

the Delaware. It will be noted how as the float was followed the quality of the water steadily improved, which still further illustrates the tendency to purification which was commented on in connection with the examination of the water made at Chester.

DELAWARE RIVER, 1914

Cross Sections

Arch Street

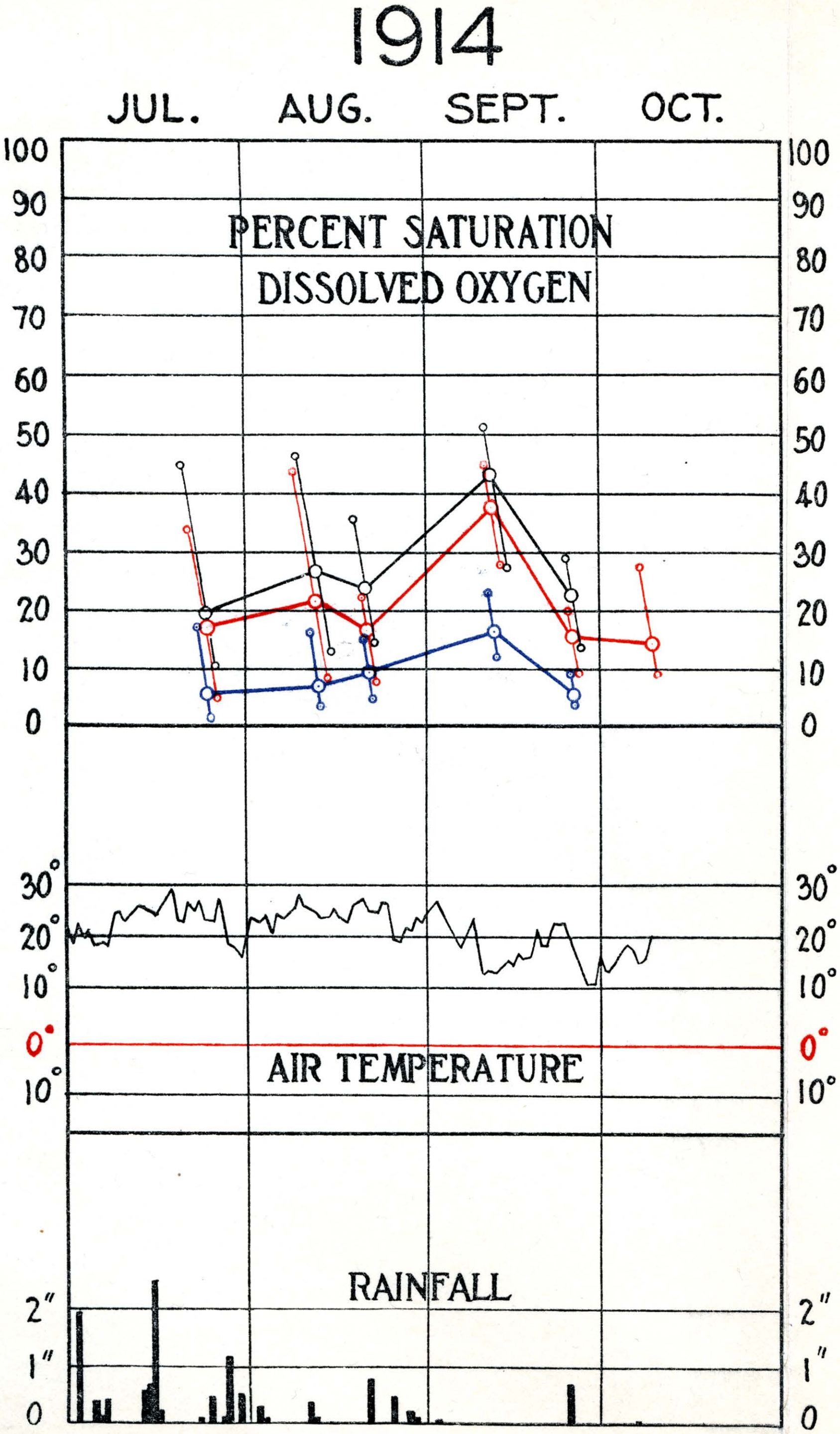
During July, August, September and October of 1914 the cross section at Arch Street was examined at approximately fortnightly intervals for comparison with the observations of 1912. Reference to the diagram in the main report will show that the average percentage saturation of the entire cross section was nearly 50 per cent. lower in 1914 than in 1912.

This condition is partly due to the long drought of the summer of 1914, and to the increased amount of sewage discharged into the river, due to increase in population and extension of the sewer system.

The diagram showing seasonal effect upon dissolved oxygen in 1914 indicates even more clearly the depletion of the oxygen during the past summer.

However, during the observations no offensive odors were noted from the river water except in the docks. It is of interest to compare the two diagrams of the Arch Street cross section with the diagrams showing tidal effect upon dissolved oxygen.

It was usually observed during 1912 at this cross section that the water contained materially more dissolved oxygen at the end of the ebb tide than at the end of the flood tide. But during 1914, while the water at high tide was frequently no worse than in 1912, the water at low tide was materially lower in dissolved oxygen. This is the cause of the lower average figures in 1914 over 1912.



CITY OF PHILADELPHIA

PLAN FOR THE COLLECTION, TREATMENT AND DISPOSAL OF SEWAGE

SANITARY SURVEYS OF THE RIVERS
SEASONAL EFFECT UPON DISSOLVED OXYGEN

DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
1914

LEGEND

EAST SAMPLING STATION BLACK.
MID STREAM SAMPLING STATION RED.
WEST SAMPLING STATION BLUE.
MAXIMUM.
AVERAGE DAYS OBSERVATIONS.
MINIMUM.

NOTE:-

THIS DIAGRAM REFERS TO THE DELAWARE RIVER AT ARCH STREET AND IS FOR COMPARISON WITH THE 1912 OBSERVATIONS.

Torresdale

On September 15, 1914, the cross section at Torresdale was examined. Results shown on diagram.

Comparing this observation with that made on September 5, 1912, it will be seen that the water at the later date is about the same as in 1912, or even slightly more oxygenated, especially at high tide.

Fort Mifflin

On August 3, 1914, the cross section at Fort Mifflin was examined. Results shown on diagram. Comparing this observation and the one made on July 24, 1912, it will be noted that notwithstanding the drought of the summer of 1914, the water of the Delaware River at this point during low tide contained practically the same amount of dissolved oxygen as two years previous.

But the water at high tide was markedly poorer, especially on the west or Pennsylvania side, where the average water toward the end of the flood tide was 1/3 lower in dissolved oxygen in 1914 than in 1912.

Float Observations

During 1914 several observations were made to determine tidal movements of the water of the rivers, and, in most cases, samples of the water were taken beside the float for examination of dissolved oxygen.

The floats used for this purpose consisted of 1½ inch x 1½ inch white pine rods 12 feet long, having at the bottom four vanes made of No. 28 galvanized sheet iron projecting 15 inches from the rod and 20 inches high. These vanes overcame the buoyancy of the wood to such an extent that the rod projected about 12 inches from the surface. Each rod was provided with a different colored flag. And if the float under observation was interfered with by the boats on the river, another float with different colored flag

was put in as near as possible to the first one. In this way it was found practical to make float observations even on parts of the river subject to heavy boat traffic.

Tidal Velocities in the Channel of the Delaware River in Front of Fort Mifflin

In order to determine the tidal velocities in the vicinity of the submerged outlets for the Southwest Works, float observations were made on August 3, 1914, by establishing range points on shore and noting the time the floats required to pass the measured course.

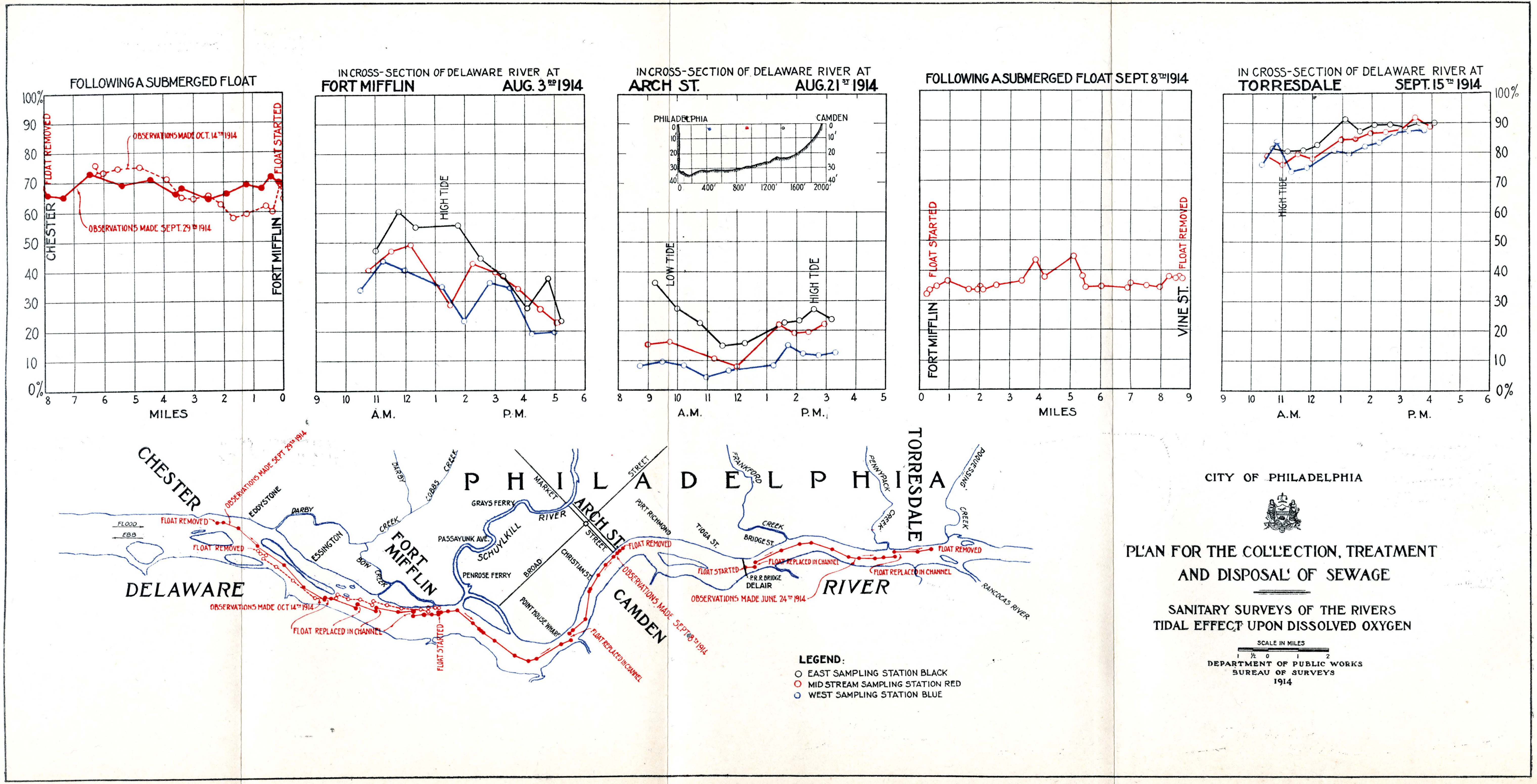
It was observed that about one-half hour after high water the velocity in the channel of the river was 1.41 miles per hour, or 2.07 feet per second.

When the ebbing tide had flowed for one hour the velocity reached 2.92 feet per second, and for the succeeding four hours the average velocity was about 3 feet per second. In the next hour the velocity was lowered to 1.8 feet per second, and reached zero at the slack water of low tide.

It is, therefore, evident that ample velocities occur at this point to maintain the fine particles of sewage matter in tank effluents in suspension, and also to cause the effluent of the Southwest Works to be rapidly diffused in the river water.

Float Observations to Determine the Flood Tide Movement Above the Outlets of the Proposed Northeast Works

This observation was made June 24, 1914. A float was placed in the channel of the Delaware River at the Delair Bridge at low water. Its velocity steadily increased, reaching a maximum of 3 feet per second at Lardner's Point, a distance of 2 1/3 miles from the Delair Bridge. For the next 2 2/3 miles the float was carried at a velocity averageing 2.2 feet per second to in front of the intake of the Tor-



FOLLOWING A SUBMERGED FLOAT
FLOAT REMOVED
FLOAT STARTED
OBSERVATIONS MADE OCT. 14TH 1914
OBSERVATIONS MADE SEPT. 29TH 1914
CHESTER
FORT MIFFLIN
MILES
IN CROSS-SECTION OF DELAWARE RIVER AT FORT MIFFLIN AUG. 3RD 1914
HIGH TIDE
A.M.
P.M.
IN CROSS-SECTION OF DELAWARE RIVER AT ARCH ST. AUG. 21ST 1914
PHILADELPHIA
CAMDEN
LOW TIDE
HIGH TIDE
FOLLOWING A SUBMERGED FLOAT SEPT. 8TH 1914
FORT MIFFLIN
FLOAT STARTED
VINE ST.
FLOAT REMOVED
IN CROSS-SECTION OF DELAWARE RIVER AT TORRESDALE SEPT. 15TH 1914
HIGH TIDE
CHESTER
DELAWARE
EDDYSTONE
DARBY
ESSINGTON
FORT MIFFLIN
BOW CREEK
DARBY CREEK
COBBS CREEK
P H I L A D E L P H I A
GRAYS FERRY
PASSAYUNK AVE.
SCHUYLKILL RIVER
PENROSE FERRY
BROAD
POINT HOUSE WHARF
MARKET
ARCH ST.
STREET
CHRISTIAN ST.
PORT RICHMOND
TIOGA ST.
BRIDGE ST.
FRANKFORD CREEK
PENNYPACK CREEK
TORRESDALE
POQUESSING CREEK
RANCOCAS RIVER
CAMDEN
RIVER
P.R.R. BRIDGE
DELAIR
FLOOD
EBB
FLOAT REMOVED
OBSERVATIONS MADE SEPT. 29TH 1914
OBSERVATIONS MADE OCT 14TH 1914
FLOAT REPLACED IN CHANNEL
FLOAT STARTED
OBSERVATIONS MADE SEPT. 8TH 1914
FLOAT REPLACED IN CHANNEL
FLOAT STARTED
OBSERVATIONS MADE JUNE 24TH 1914
LEGEND:
EAST SAMPLING STATION BLACK
MID STREAM SAMPLING STATION RED
WEST SAMPLING STATION BLUE
CITY OF PHILADELPHIA
PLAN FOR THE COLLECTION, TREATMENT AND DISPOSAL OF SEWAGE
SANITARY SURVEYS OF THE RIVERS
TIDAL EFFECT UPON DISSOLVED OXYGEN
SCALE IN MILES
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
1914

resdale water filters. The end of the flood tide carried the float one mile farther to the mouth of Rancocas River at steadily decreasing velocities.

Float Observations to Determine the Ebb Tidal Movement of the Delaware River from Fort Mifflin

The observations of July 10, 1912, have been already described and shown by diagram. This work was repeated three times during 1914. On September 1, 1914, a float was placed in the channel of the Delaware River at Fort Mifflin at high tide. It was carried by the ebbing tide only as far as Essington, a distance of five miles.

The probable cause of this was that there was a strong southwest wind blowing (20 miles per hour), which caused a retardation of the ebb tide, which turned two hours later than normal at Fort Mifflin.

Dissolved oxygen samples showed practically no variation from 50 per cent. saturation of the water along the path of the float.

On September 29, 1914, this work was repeated and results are shown on the diagram, "Tidal Effect upon Dissolved Oxygen." This time the ebbing tide carried the float to Chester, a distance of 8.06 miles in 5½ hours. The velocity of flow stadily increased for the first three hours, when a maximum of 3.2 feet per second was reached, and during the remainder of the observation steadily decreased.

The samples of the water taken beside the float and examined for dissolved oxygen showed very little change in the condition of the water, which averaged 67 per cent. saturation.

On October 14, 1914, the work was again repeated. This time the float was carried by the ebbing tide to a point opposite the mouth of Darby Creek, a distance of about six miles, in 4¾ hours.

Samples of the water taken from beside the float and

examined for dissolved oxygen showed but little improvement in the quality of the water for the first three hours of tidal flow. After that the amount of dissolved oxygen in the water gradually rose from 60 per cent. to 75 per cent. saturation.

Float Observations to Determine the Flood Tide Movement Above the Outlets of the Proposed Southwest Works

On September 8, 1914, a float was placed in the channel of the Delaware River in front of Fort Mifflin at the beginning of the flooding tide.

The rising tide carried the float past the mouth of the Schuylkill River, along a path that showed no tendency toward the west bank of the Delaware. This is an important condition, as it indicates that the great volume of effluent from the Southwest Works will be carried up the Delaware River with ample dilution.

The float was carried by the rising tide 8½ miles in six hours to a point opposite Vine Street, when slack water occurred.

The velocity of the river was very variable, the maximum rate being 4.2 miles per hour, or 6.05 feet per second, and the normal minimum being one mile per hour, or 1.5 feet per second.

These velocities are now keeping the bed of the river clean, and, therefore, can surely be depended upon to prevent any sludge deposits in the future when the sewage is freed from its settleable matter by treatment.

Samples of the water were taken at frequent intervals as the float moved up stream and examined for dissolved oxygen. The results show that there was practically no change in the water as it flowed from Fort Mifflin to Vine Street. It must be borne in mind that sewage was continually being added to the river as the float moved up stream.

SCHUYLKILL RIVER

Float Observations

Flood Tide from the Mouth of the Schuylkill

On July 22, 1914, a float in the channel of the Schuylkill River at its mouth at low water was carried a distance of 1.38 miles, at an average velocity of 1.20 miles per hour or 1.76 feet per second. Shortly after passing Penrose Ferry Bridge the velocity of the float rapidly decreased until it reached a point about 1,000 feet northwest of the bridge, when it practically stopped. It then resumed its movement and traveled about .6 of a mile at a velocity of .48 of a mile per hour or .7 foot per second. It turned back at a point above Stone Street. The total distance which the flood waters carried the float up the Schuylkill River was 2.38 miles in 3 hours 46 minutes. The stopping of the float beyond Penrose Ferry Bridge is a phenomena spoken of by those familiar with the river as the "rebound of the tide," and it is probably caused by the meeting of the flood waters with the down stream flow of the river, whereby the river surface is raised without much forward movement of the water, until a condition is established whereby a hydraulic gradient is produced and the forward movement of the flood tide continued. It will be noted that the second half of the float's run was at a velocity less than sufficient to carry in suspension materials susceptible of removal in a grit chamber.

Part of Ebb Tide from the Outlet of the Mill Creek Sewer

As soon as the float was removed the boat was taken to the outlet of the Mill Creek sewer, where it appeared that the tide had already fallen 12 inches to 18 inches. The float was placed in the river at this point. The remainder of the ebb tide carried it two miles down stream in 6½ hours,

or at an average velocity of less than ½ foot per second. At this velocity material of an organic nature will settle.

Tidal Movements in the Vicinity of Spring Garden Bridge

On September 14, 1914, at 7.00 A. M., a float was placed in mid-channel of the Schuylkill River about 1,200 feet below Fairmount Dam. The float indicated a down stream movement of the water, although the water surface was still rising. This condition continued for two hours, when the water surface began to fall, indicating a real ebbing tidal movement. At 3.45 P. M. the tide turned and the float began to move up-stream again. At 7.00 P. M. the float was removed, due to the inability to see points on shore for location.

During the observation the wind was from the East and at about 5 miles per hour, which twice required the replacement of the float in the channel.

The total downward movement of the float was only 700 feet and upward 500 feet, indicating velocities so low that sewage solids are readily deposited on the bottom .

From the above observations, it appears that the water in the vicinity of Spring Garden Street Bridge progresses about 200 feet on each cycle of tide, which distance would be greatly lengthened during time of freshet. It also is to be noted that there was a down-stream movement during the last two hours of each flood tide.

For the first seven hours of the observations all samples of the water showed about 20 per cent. saturation with dissolved oxygen, which uniformly decreased during the succeeding five hours to 8 per cent. as a minimum.

DEPOSITS ON THE RIVER BOTTOMS

In order to determine whether the depletion of dissolved oxygen in the water of the Schuylkill and Delaware Rivers

was caused wholly by the sewage added each day or whether part was due to the decomposition of sludge deposits, careful examinations of the two rivers were made to locate the presence and find the condition of deposits on the bottom.

Methods Used

Field

The samples of the river bottom were obtained from a boat whose location was determined at the time of sampling by sextant observations of known locations on shore.

Several types of apparatus were tried in order to obtain samples, even when the deposit was hard and of only a thin layer. The form finally adopted consisted of a heavy galvanized cylinder six inches in diameter and nine inches long. The top had a hinged cover capable of being raised only and with a rubber gasket seat, so that when the apparatus was hauled up the sample would not be washed out. To the lower part of the cylinder was soldered a galvanized iron cone in which lead was poured to weight the point. About where the cone joined the cylinder were four round holes one inch in diameter and provided on the inside with hinged valves only capable of opening inward.

When this apparatus was lowered to the bottom it sunk in the deposit which was admitted to the inside through the four small holes. It was then moved up and down a few times to cause it to fill more completely. The valves prevented the deposit from flowing out or water flowing in while it was hauled to the boat. The supernatant water was poured off and a pint jar filled with the deposit, its characteristic noted, such as "sandy," "foul odor," "thin mud," etc.

Laboratory

The samples were not examined in the laboratory until the following day.

When the jars were opened the odor was noted, and gas tested with a flame to determine if it was inflammable; if not, the contents of the jar were stirred and again tested by flame. 50 cc. of the deposit was placed in a pint jar, which was filled with aerated tap water. This was kept at room temperature for about five days, when the amount of dissolved oxygen consumed by the deposit was determined to show the putrescibility or stability of the sample.

The sample in the original jar was emptied into a sand sieve having 20 meshes per inch, which was then alternately moved up and down in a flat cylindrical glass vessel containing clean water. This washed the finely divided mud through the sieve. The operation was completed by using fresh water until the debris in the sieve was freed from mud.

In undoubtedly polluted samples the microscopist had no trouble in at once fishing out characteristic debris of sewage origin. From samples not grossly polluted the debris was fished out of the screen and cleared up in 10 per cent. hydrochloric acid, then mounted in gylcerine and examined under the microscope.

Permanent mounts were made of various materials, such as fibre from linen, silk, wood, vegetables and different kinds of meats. To these were added known objects recovered from the samples. These served as standards for the identification of unknown objects obtained from the river bottom.

Conclusions

It was reasonable to expect that samples which exhausted the dissolved oxygen in the laboratory, formed inflammable gas and emitted foul odors, were of sewage origin, and that samples which did not materially exhaust the dissolved oxygen, did not produce gas and were inodorous, would not contain evidence of sewage pollution.

These two statements were well borne out by the observations. The interesting features observed were the exceptions, among which the following may be noted:

A sample collected on the New Jersey side of the river at the end of the water works wharf showed no evidence of sewage pollution when examined microscopically, no gas was formed in the sample, and it did not have an offensive odor. The sample, however, completely exhausted dissolved oxygen in the tap water added to it in at least four days. This inconsistency is explained by the presence of a large number of snails in the sample and serves to show that methods of examining river mud based entirely upon chemical observations may lead to fallacious conclusions.

On the other hand, samples which the microscopist reported as containing ample evidence of sewage pollution did not materially exhaust the dissolved oxygen, did not form gas and were practically inodorous.

The interpretation of this anomaly may be that while the deposit from which this sample was taken was originally of sewage origin, fermentation and decomposition had so destroyed the organic matter in the deposit that it was no longer in a putrescible condition and only the more resistant structures, such as hairs, linen fibres and cellulose still remained to indicate the original source of the deposit.

This would show that conclusions based solely upon microscopical observations are not complete and that fair conclusions can only be drawn from observations including microscopical examination, physical observations and a determination of the putrescibility of the sample as measured by its power of deoxygenating water.

In the accompanying table the characteristics of some of the samples are given, which support these ideas.

Remarks	Consistency: Gravel	Grit	Mud & Grit	Mud	Semi-Solid	Color: Grey	Mottled	Black	Odor: None	Tar	Coal Gas	Petroleum	Bilge Water	Foul	Gas was inflammable	Gas was formed	Microscopic examination showed: No evidence of sewage pollution	Doubtful evidence of sewage pollution	Positive evidence of sewage pollution	Percent of dissolved oxygen consumed by sample (25 — 50 — 75)	Sample Number
			●			●								●	+	+			●		57
				●				●						●	+	+			●		19
			●			●								●	+	+			●		50
				●		●					●				+	+			●		71
				●		●					●				+	+			●		82
				●				●			●				+	+			●		84
			●			●					●				+	+			●		43
			●					●				●			+	+			●		11
			●			●								●		−			●		46
			●			●							●			−			●		74
			●					●	●						+	+			●		13
			●			●							●			−		●			70
CONTAINED SNAILS						●							●			−	●				78
				●		●					●				+	+			●		48
				●		●							●		+	+			●		45
		●				●					●				+	+			●		73
				●				●				●			+	+			●		14
				●		●							●			−			●		65
AT PIERHEAD		●					●						●			−		●			42
CONTAINED SNAILS			●			●			●							−		●			36
CONTAINED STREET WASH		●					●						●			−	●				47
				●				●		●					+	+			●		29
				●		●					●				+	+			●		49
				●				●					●		+	+			●		21
				●		●							●			−			●		9
			●			●							●			−			●		8
				●		●					●				+	+			●		76
				●		●							●		+	+			●		83
	●						●				●					−			●		12
CONTAINED SNAILS				●			●						●			−	●				39
CONTAINED CLAMS			●			●							●			−	●				60
CONTAINED SNAILS AND CLAMS				●		●			●							−	●				72
CONTAINED SNAILS		●				●							●			−	●				35
				●		●			●							−			●		79
				●		●					●				+	+			●		86
				●		●						●			+	+			●		22
			●			●							●			−		●			44
				●		●						●				−			●		68
				●				●					●		+	+			●		17
				●				●				●			+	+			●		23
					●	●			●							−		●			31
OPPOSITE MOUTH OF FRANKFORD CREEK					●	●			●							−	●				27
		●				●			●							−			●		69
				●		●						●			+	+			●		25
				●		●					●				+	+			●		41
				●		●			●							−			●		64
				●		●							●		−	+			●		67
			●			●							●			−		●			71
			●			●							●			−			●		85
							●		●							−			●		77
MOUTH OF PENNYPACK CREEK			●			●			●							−		●			33
			●			●					●					−		●			59
				●		●				●						−			●		62
				●		●			●							−		●			53
			●				●					●				−			●		26
CONTAINED WORMS.		●				●						●				−	●				54
		●						●	●							−		●			30
				●		●								●	+	+			●		24
				●		●			●							−			●		80
				●		●			●							−		●			63
			●			●			●							−	●				61
					●	●			●							−	●				34
		●					●		●							−	●				75
		●				●			●							−		●			52
		●				●			●							−	●				55
		●				●			●							−	●				37
		●				●			●							−	●				56
		●				●			●							−		●			32

RESULTS OF EXAMINATIONS

OF SAMPLES OF DEPOSITS TAKEN FROM THE BOTTOM OF THE

DELAWARE & SCHUYLKILL RIVERS

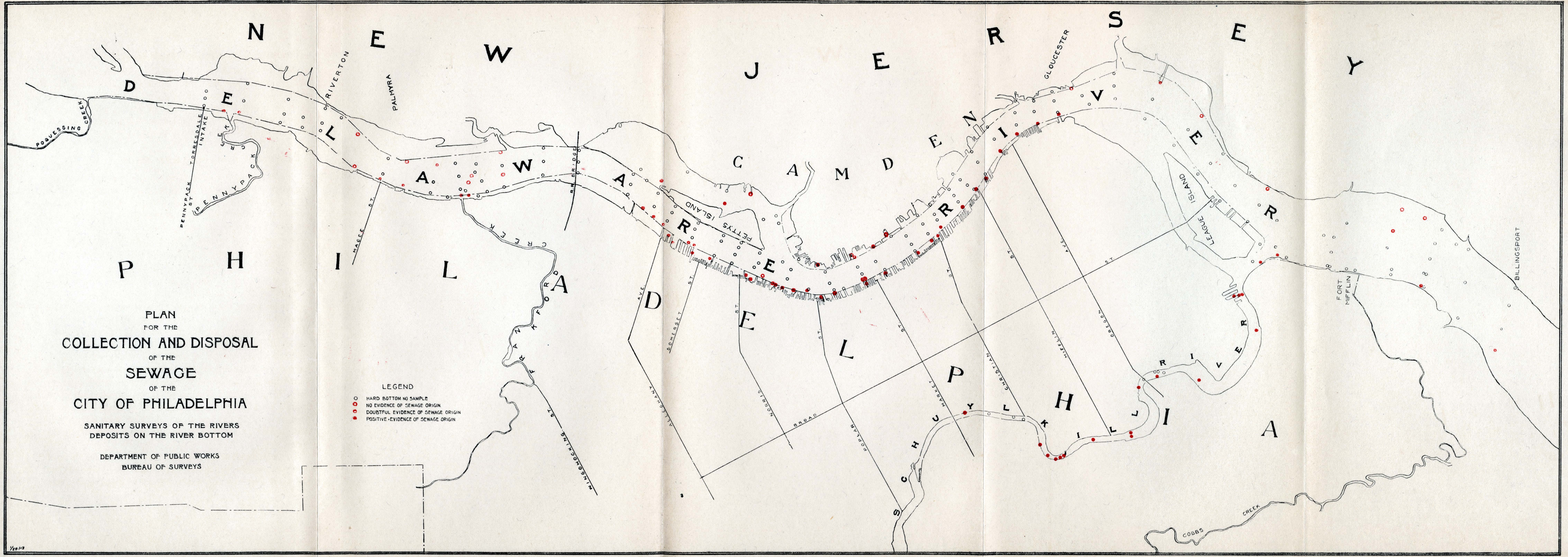
AT

PHILADELPHIA

NOTE:—

THE LOCATION OF THE SAMPLES SHOWN ON PLAN.

DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
SEWAGE DISPOSAL DIVISION


NEW JERSEY
DELAWARE RIVER
CAMDEN
PHILADELPHIA
SCHUYLKILL RIVER
POQUESSING CREEK
PENNYPACK CREEK
PENNYPACK ST
TORRESDALE INTAKE
RIVERTON
PALMYRA
MAGEE ST
RR BRIDGE
FRANKFORD CREEK
FRANKFORD
WINGOHOCKING ST
PETTYS ISLAND
ALLEGHANY AVE
SOMERSET ST
NORRIS ST
BROAD ST
POPLAR ST
MARKET ST
CHRISTIAN ST
MIFFLIN ST
OREGON AVE
GLOUCESTER
LEAGUE ISLAND
FORT MIFFLIN
BILLINGSPORT
COBBS CREEK
PLAN
FOR THE
COLLECTION AND DISPOSAL
OF THE
SEWAGE
OF THE
CITY OF PHILADELPHIA
SANITARY SURVEYS OF THE RIVERS
DEPOSITS ON THE RIVER BOTTOM
DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
LEGEND
HARD BOTTOM NO SAMPLE
NO EVIDENCE OF SEWAGE ORIGIN.
DOUBTFUL EVIDENCE OF SEWAGE ORIGIN
POSITIVE EVIDENCE OF SEWAGE ORIGIN

Condition of the Schuylkill River Bottom

As a result of the examinations it is known that the entire bottom of the Schuylkill River from Fairmount dam to its mouth is covered with deposits of sewage origin, excepting in the vicinity of Christian Street, where there is a rock bottom and higher velocities of flow, and at Oregon Avenue, where there is a sharp bend in the river.

Condition of the Delaware River Bottom

The examinations show that the docks along the Delaware River, particularly at or near sewer outlets, contain very considerable amounts of sewage sludge. With this exception, however, the entire bottom of the Delaware River between Torresdale and Billingsport is free from deposits of sewage origin. In fact, with very few exceptions, it was not possible to collect samples, due to the hardness of the river bottom.

Conclusions

The probable cause of the dirtiness of the bed of the Schuylkill Rover and cleanliness of the bed of the Delaware River is the low velocity in the former and the high velocities in the latter.

When crude sewage is discharged into a water course having velocities insufficient to maintain the solid sewage matters in suspension, sludge deposits are formed upon the river bottom and the decomposition and putrefaction of the organic constituents in the absence of oxygen result in the production of liquids and gases which are both offensive in odor and with a high avidity for the dissolved oxygen in the water.

These decomposition processes are retarded by the cold of winter, and hence the deposits accumulate at a time when the water contains the greatest amount of dissolved oxygen,

and is therefore best able to receive, without offence, the products of decomposition.

With the rise of temperature of spring, the biological forces resume activity, reaching a maximum in the summer. Unfortunately, the river water at this time normally contains less dissolved oxygen than in the winter, and the greatest demand is placed upon the oxidizing power of the river at the time when it is least able to cope with the situation.

When, however, sewage is discharged into water courses having velocities sufficient to maintain the solid matters in suspension, no deposits will form, except in eddies and docks, and if the volume of diluting water is sufficiently great to more than equal the demands of the sewage for oxygen, the suspended solids will be carried forward surrounded by oxygenated water, and will become ultimately purified by the natural biological forces of the river water without the creation of any offence.

In the Delaware River at Philadelphia, where the tidal velocities maintain the sewage matters in suspension, they are by successive oscillations carried down stream toward the ocean. The only load placed upon the river is from the sewage each day discharged into it.

This is a valuable asset to the City of Philadelphia, for it allows a much lower percentage of dissolved oxygen to exist in the Delaware River without danger of nuisance than if there were putrefying sewage sludge upon the river bottom.

APPENDIX E

REPORT OF THE PRINCIPAL ASSISTANT ENGINEER UPON AN EXAMINATION OF SYSTEMS OF SEWAGE DISPOSAL IN THE PRINCIPAL CITIES IN EUROPE, WITH DEDUCTIONS AND COMPARISONS, AFTER AN INSPECTION IN APRIL—JUNE, 1913

CITIES EXAMINED

GERMANY: Hamburg, Bergedorf, Leipzig, Dresden, Berlin, Potsdam, Cöpenick, Munich, Frankfurt a/M, Wiesbaden, Cologne, Elberfeld, Barmen, Düsseldorf, Essen Nord, Essen Nordwest, Essen—Wanne Nord, Holzwickede, Bochum, Gelsenkirchen Nord, Oberhausen, Recklinghausen.

AUSTRIA: Vienna

HOLLAND: Amsterdam.

FRANCE: Paris.

BELGIUM: Brussels.

ENGLAND: London—Barking; Crossness; Chingford (Pumps); Hampton; Birmingham—Saltley and Minworth; Sheffield; Wakefield; York; Leeds; Huddersfield; Bradford; Manchester; Salford; Bolton; Blackburn; Accrington and Church; Liverpool.

Note: References to a plan for the City of Philadelphia apply to the incompleted studies as they existed prior to this examination, and not to the plan described and recommended in the main report, which has been made to embody such recommendations herein, which it was thought wise to adopt.

ABSTRACT

Conclusions; Application of Conclusions and Recommendations for Philadelphia, for Collecting System; Points of Disposal; Relation to Garbage Disposal; Methods of Disposal; Approximate Economies by Recommendations, if present tentative plan be remodelled.

The more detailed report consists of the following: Introduction; Status of the Art of Sewage Disposal; Reasons for and Scope of the Inquiry; Relative values of the information received from the different countries visited; Chapters devoted to German works, French works, Dutch works and English works. Then follows—Comparisons of German and English works, Comparisons of American works with English and German, which leads up to the main conclusions, placed first in the report.

Appendices containing detailed descriptions of the works in the different cities visited with criticisms and comments are on file.

PART I

CONCLUSION

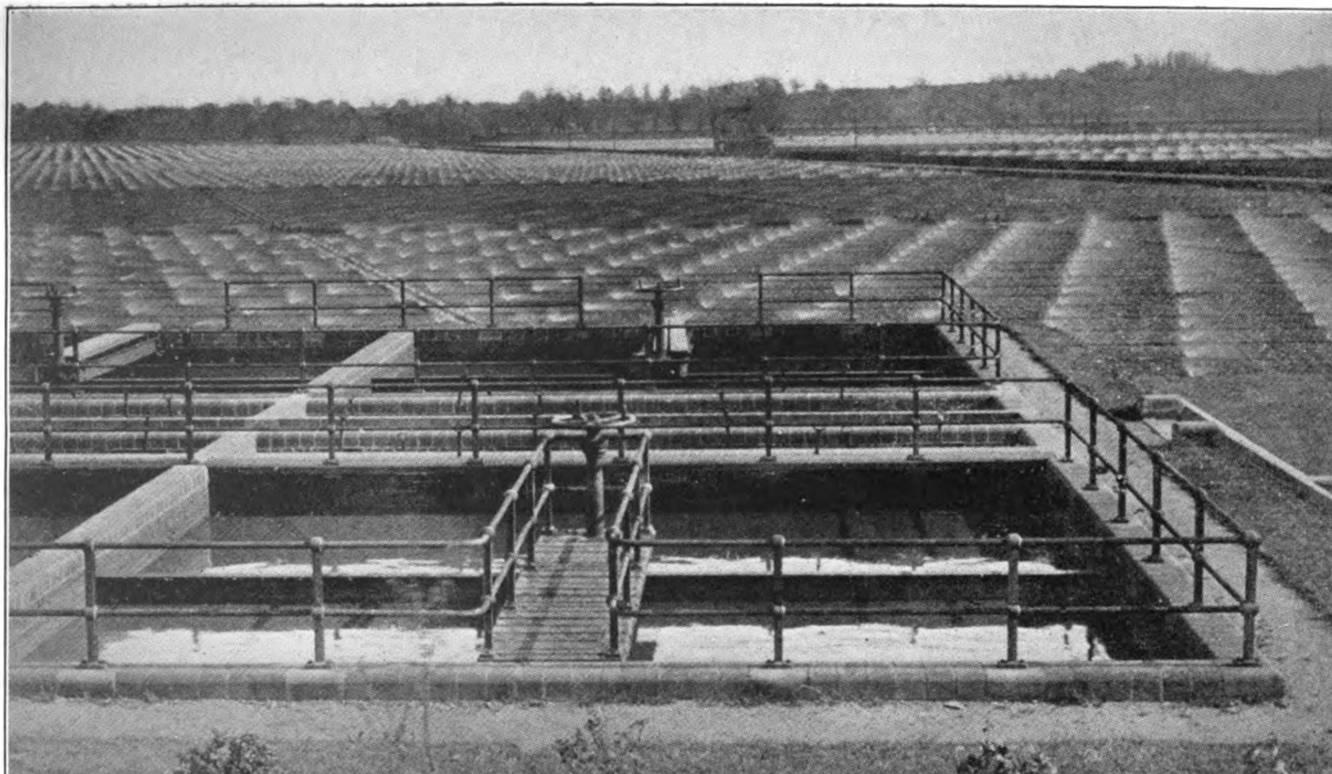
Study of European sewage disposal works is valuable as reflecting conditions which may exist here in 25 years.

The establishment of Government Rivers Boards to supervise sanitary conditions and works proposed is essential to proper results.

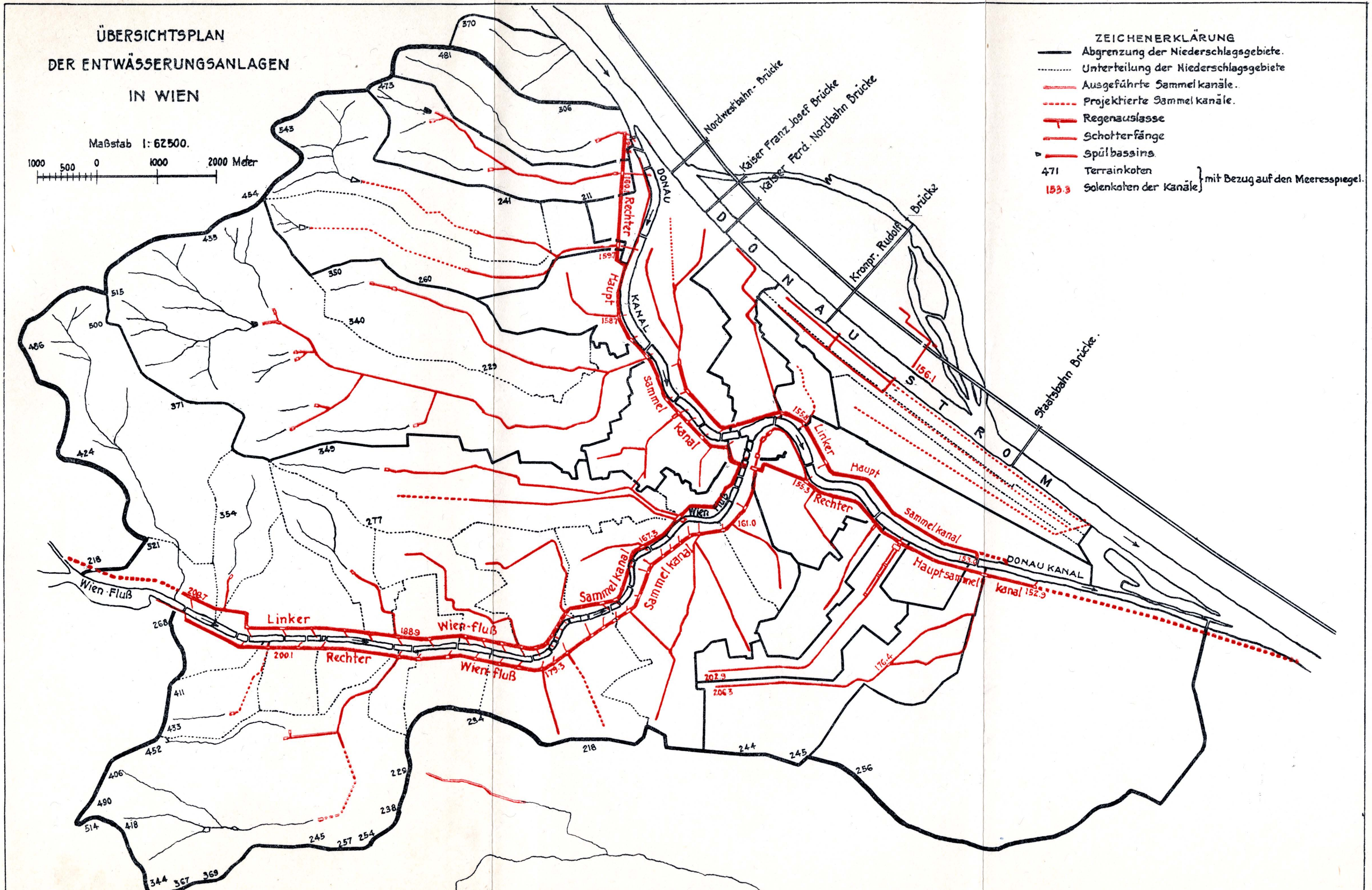
The art of sewage disposal is advancing, has appeared to stop at percolating filters, but an adequate and less costly substitute is anticipated.

It is practicable at present to obtain from a properly designed and operated sewage works a clear, odorless, sparkling and non-putrescent effluent, from a sewage of extreme concentration, even if it has become septic.

Sludge resulting from sewage treatment can be rendered



Silt Tanks and Percolating Filters, Minworth, Birmingham, England.



ÜBERSICHTSPLAN
DER ENTWÄSSERUNGSANLAGEN
IN WIEN
Maßstab 1: 62500.
1000 500 0 1000 2000 Meter
ZEICHENERKLÄRUNG
Abgrenzung der Niederschlagsgebiete.
Unterteilung der Niederschlagsgebiete
Ausgeführte Sammelkanäle.
Projektierte Sammelkanäle.
Regenauslasse
Schotterfänge
Spülbassins
471 Terrainkoten
153.3 Solenkoten der Kanäle
mit Bezug auf den Meeresspiegel.
Nordwestbahn-Brücke
Kaiser Franz Josef Brücke
Kaiser Ferd. Nordbahn Brücke
Kronpr. Rudolf Brücke
Staatsbahn Brücke
DONAU STROM
DONAU KANAL
Rechter Haupt Sammelkanal
Linker Haupt Sammelkanal
Wien-Fluß
Linker Wien-fluß Sammelkanal
Rechter Wien-fluß Sammelkanal
Hauptsammelkanal

innocuous, practically inodorous, wholly unobjectionable and can be disposed of without nuisance, sometimes profitably.

By certain combinations of treatment, desired results may be secured at a fraction of the cost of other recognized scientific methods of treatment, in satisfactory operation.

It is considered that, in the conservation of a water supply, sewage disposal systems should bear only their proportion of the cost of treatment.

The construction of properly designed, economical and sanitary collection system is the first essential in sewage disposal.

The use of the separate system of sewer conduits is inadequate and has been abandoned for urban districts.

Combined systems are the most effective in urban areas, where *all* the polluted liquids during dry weather flow can reach the disposal works.

Polluted streams can effectually be made clean by a system of interceptors to prevent sewage from reaching the stream. To properly construct these interceptors and their connections calls for the highest designing and constructive skill.

Rivers may be clean and be without nuisance to sight and smell, with simple screening or with tankage treatment added, if the diluting volume of river flow is sufficient, and if the velocity be enough to prevent deposits.

Rivers act as oxidizing agents, so that even raw sewage, discharged into them, which may have reduced their dissolved oxygen contents, does not permanently pollute them. After a few miles, the river reabsorbs oxygen and recovers. Where not used as a water supply, the extent to which a river may be used thus offers a problem to be determined.

At the present stage of the art, there is no process that gives better tankage results, nor better sludge digestion, without odor or nuisance, and by which the sludge can be

more cheaply disposed of, than the form of tank used on the works of the Emscher Genossenschaft in Germany.

Should screening be desired, the so-called Reinsch screens as used at Dresden, Germany, are the most cleanly and efficient on any plant that was observed.

It has been proved by experience that adequate tankage treatment is more effective and less costly than the operation of fine screens.

Of the bacterial treatments, the percolating filter furnishes the best result, both in oxidizing the organic matter and in the removal of putrescibility. The speed of operation is greater than by any other system, with consequent reduced first cost for land areas.

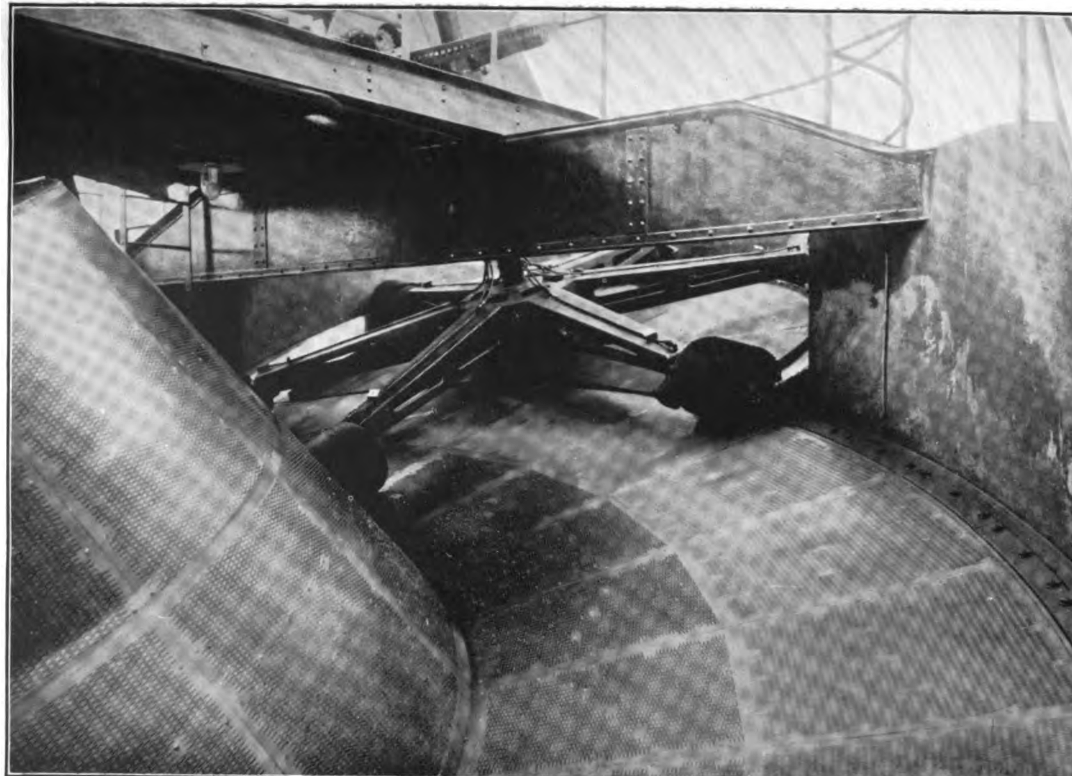
When sufficient fats are present in the sewage, they may be profitably recovered from sludge. Drying for fertilizer and fuel use has also proved profitable in some cases.

The advisability of determining finally to employ percolating filters on areas of such magnitude as would be required in Philadelphia, is questionable, as it is without a precedent. Lacking anything better at present, it may be held to, tentatively.

Submerged outlets from a disposal works are essential for proper dilution.

Disinfection with hypochlorite of lime as a final treatment is not in use, either in England or Germany. In the conditions of the rivers in the former country, it would not be effective in removing pollution.

It is fallacious to adhere to a policy of constructing at once an ideal sewage disposal system. It should be practical and efficient under final conditions and should advance thereto by gradations determined by the conditions in the river into which final disposition is to be made.



Cleaning Brushes on Reinsch Screen, Dresden, Germany.

APPLICATION OF THE CONCLUSIONS TO AND RECOMMENDATIONS FOR PHILADELPHIA

Collectors

For some time past the writer has been convinced that the great difficulties confronting the city in constructing a collecting system could be overcome by reducing its cumbersome proportions. His examinations have convinced him of its possibilities and attractiveness, provided other important recommendations shall be accepted.

In the first place, he is prepared to recede from a position which, following American practice, provides that interceptors be built along the rivers, passing underneath the existing sewers whose inverts are at the level of low water at the rivers. This plan is extremely costly, on account of the sewers being so far under the water level, with consequent difficulty as to foundation. Another great expense by following the present plan is the construction of tide gates and chambers, under disadvantages due to tidal influences, at practically every existing outfall.

He is convinced that over a large part of the territory the interceptors can be raised many feet and be so built across the section of the existing sewers as to permit of the extrados of the interceptors forming dams, excluding the tide and saving the cost of tide gate chambers, and also constitute overflows for storm flow, the dry weather flow connecting by proper sized and adjustable channels to the interceptors.

Where conditions are favorable, high level interceptors may also be built, to reduce the cost of pumping, and sewers be built, to carry drainage away from the river back to the interceptors, where possible; or if not, smaller pumping areas be allowed to remain, which can be readily operated by modern automatic pumps.

Alterations of Sections

Another economy may be accomplished by so narrowing the widths of the sections and increasing the heights as to make the trenching less costly, in which is the main expense.

The writer is of the opinion that more saving can be accomplished in remodelling the collecting system plan than in the sewage disposal plants, this, however, requiring detailed study.

Points of Disposal

From observations and impressions gained in both Germany and England, bearing upon the appearance of plants for sewage disposal and conditions surrounding them, indicating that they can be operated without nuisance, as proved by new private building operations which are springing up alongside of plants, noticeably at Essen, Birmingham and Salford, the writer is in favor of decentralization of sewage works.

As sewage works can be operated without nuisance, it is not necessary to go so far away from habitations for points of disposal. An ideal point of disposal would be at the intersection of the Delaware River and the Back Channel. Were it not for other important projects for port development, and this site were available, the amounts by which the present plan as estimated could be reduced are as follows:

For deep sewer, line of Oregon Avenue.	$1,370,000
Siphon under Schuylkill River........	1,229,000
	$2,599,000

However, taking into account the advance in price asked for land south of Jones' Lane, from an assessed valuation of about $1,000 to $5,000 and upward per acre, as com-

pared with land at $600 on the west side of the Schuylkill River, the location of a plant for sewage disposal at this point is untenable.

As an abstract proposition, the establishment of more than two points of disposal would be advantageous, in that the sizes of the interceptors would be reduced, as the volumes to be carried for long distances would be much less, with a considerable saving.

But lacking available land, it is difficult to secure suitable locations for more than two plants.

Reduction in Cost of Collecting System

Considerable progress has been made toward reducing the cost of the collecting system, as for example, the substitution of the deep crosstown sewer from the Delaware to the Schuylkill River in place of a pumping station and expensive forcemains, originally proposed, at a saving of two million two hundred thousand dollars in first cost, including the capitalized operating expense.

Pumping Stations

Examinations made of modern pumps abroad have convinced the writer that more compact and efficient pumps than those called for in the designs already prepared for the Philadelphia works, can be installed at a great saving in cost of buildings, machinery and operation.

Modern pumps are so compact that a plant for pumping under low lifts at the rate of 300 millions of gallons a day can be housed in a comparatively small building; and if the well known economy of gas producers be utilized, the operating expense will be much reduced.

These suggestions do not militate against the designs as they have been made, but recent satisfactory trials of new inventions in the pumping world, make a review of this feature necessary.

Siphons

The number and satisfactory performance of inverted siphons in use in many European cities has served to confirm the writer in an opinion advanced some years ago, and always adhered to, that where by the use of a satisfactorily designed siphon on a high level sewer, the liquid can be raised by the head in the conduit to discharge upon a disposal works by gravity, it is against public policy to waste the head and resort to pumps. This principle can readily be applied to the proposed Northeast Works at a saving of one-half the pumping now provided for.

Sludge Disposal

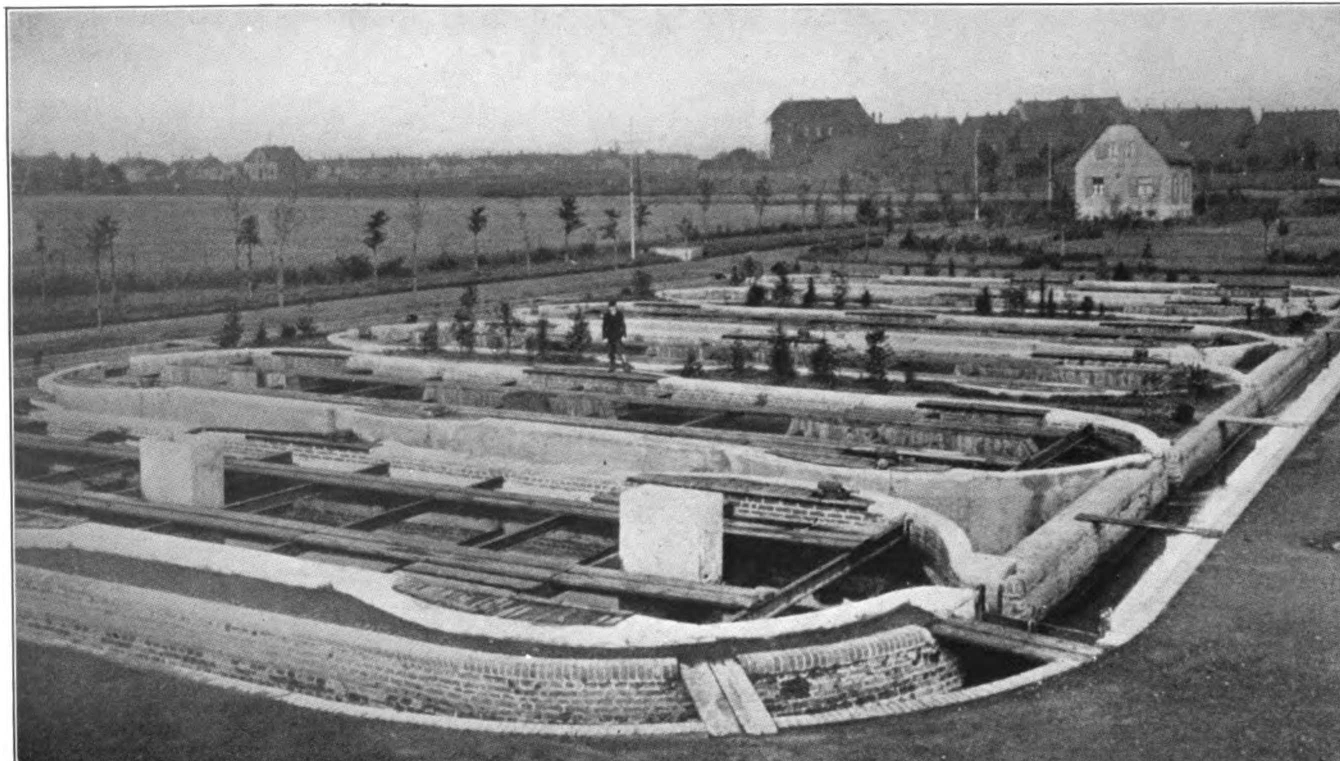
The fact that sludge properly digested can be used for filling low ground without nuisance will make the purchase of sludge steamers unnecessary.

Garbage Disposal

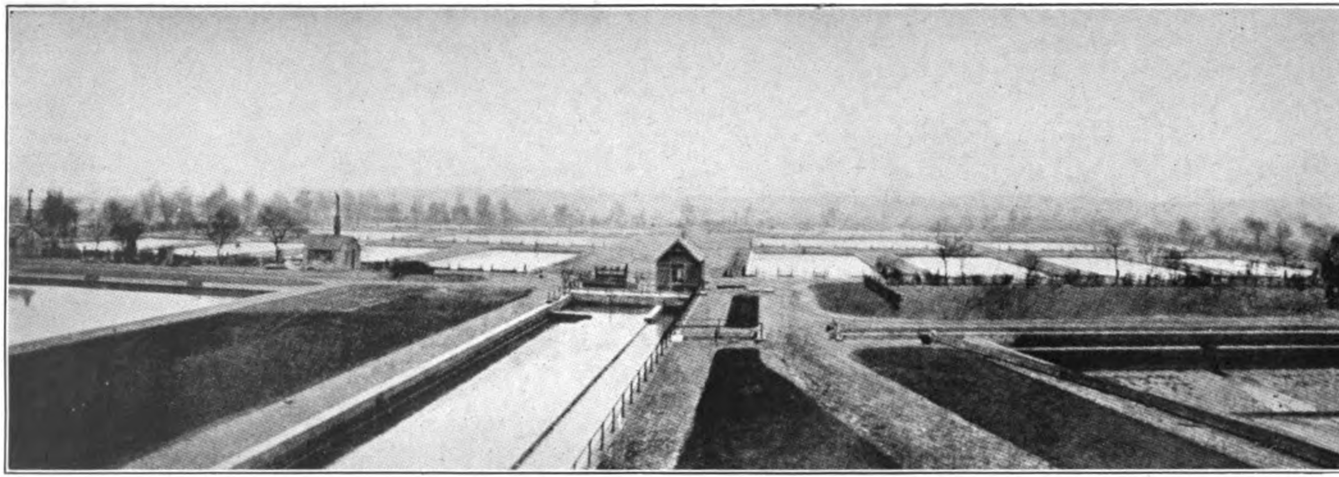
The electric power to be obtained from a properly operated garbage disposal plant, even if bye products are not recovered, coupled with the additional fuel value of sewage sludge, an example of which is at Frankfurt a/M., furnishes an inviting field for experiment to determine whether or not all the pumping at sewage disposal plants could not be done with power furnished from garbage disposal plants attached thereto, the cost of collection being paid thereby.

Final Sedimentation

Observation of European plants has served to confirm the wisdom of a decision, reached sometime ago, to abandon the idea of settling the effluent from the percolating filters before discharging to the rivers, thereby saving an initial expense of approximately $1,040,000, and an annual operating cost of $145,000.



Emscher Tanks, Bochum, Germany.



General view of Sedimentation and Sludge Digesting Tanks at the Saltley Outfall Works for Birmingham, England. Population 960,000.

The nature of the solids in a percolating filter is such as to cause them to adhere to the surfaces of the filter until mineralized, and the fact of their passing the filter is in itself a sufficient guarantee of a condition that will not be detrimental to a river, especially one in which the velocity is sufficient to prevent deposits.

Acreage in Disposal Plants

Observations and inquiries, made with a view of determining by comparison the acreage of land advisable to take for a given population, showed that in Germany, treatment was carried on upon one-tenth the area required in England for an equal population.

Making all due allowances for differences in treatment, and having in mind the fact that new building operations are proceeding very close to existing works in both countries, the writer is of the opinion that a more moderate area than that proposed may be taken for sewage plants, without reasonable grounds for complaint of nuisance, with resulting economies.

Distribution in its Relation to Loss of Head

It is a self-evident fact that the only land available for sewage plants is low and must be filled in by river dredgings for many feet before being used. On account of the magnitude of the areas, anything that can be done to reduce the filling is an inviting proposition.

The writer is therefore of the opinion that some of the English ideas for distribution on percolating filters, by which there may be caused much less loss of head through the works, should be adopted; or a modification in the so-called American methods of distribution, and the lessening of grades on a collecting system for percolating beds or both, to the end that some millions of cubic yards of filling may be saved.

Methods of Disposal

The observations made of the sewage disposal works of foreign cities, instead of militating against the present proposed methods of disposal in Philadelphia, served to confirm the wisdom of the conclusions which have been made.

But four things are necessary to consider:

Properly located works.

Proper tank design.

Disposal of sludge without nuisance.

An effluent which will better existing conditions in the rivers.

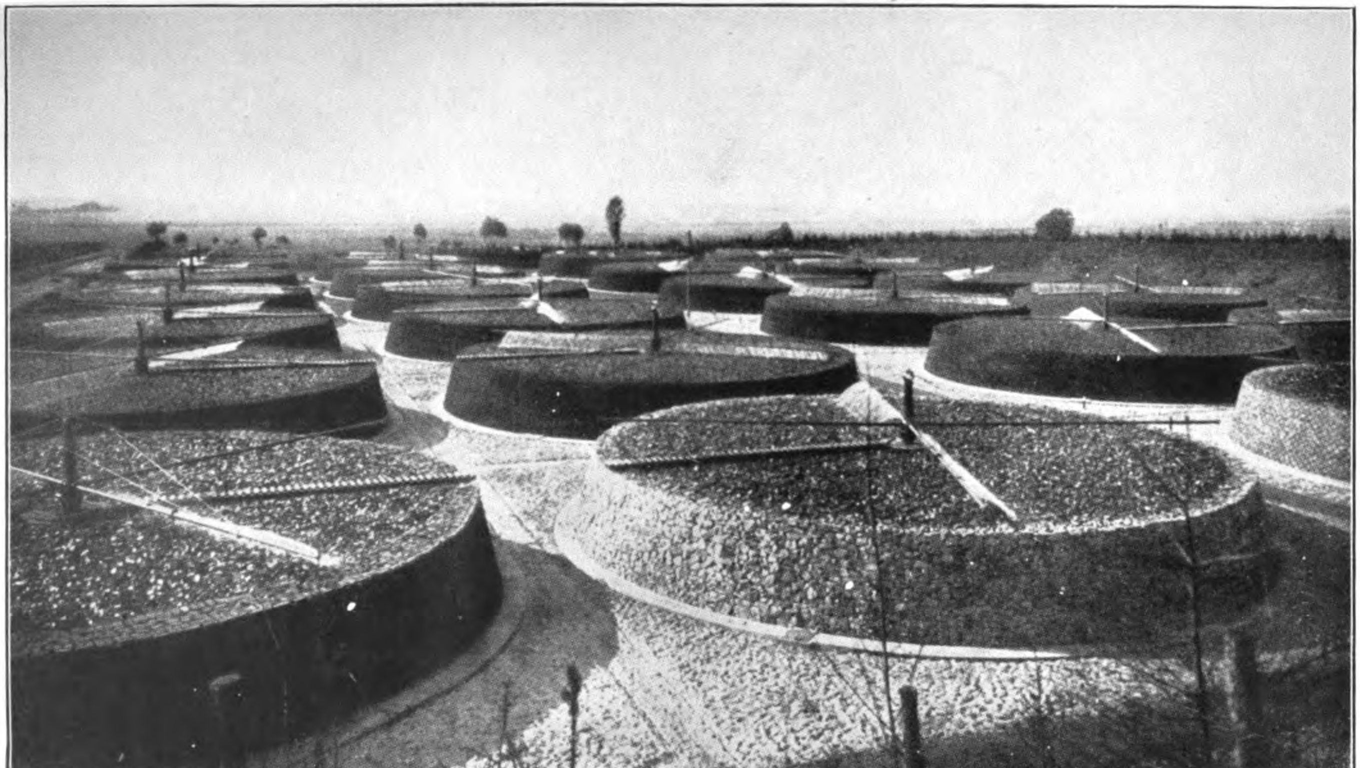
The first is a matter of good judgment; the second and third have been solved by our own Bureau in the Pennypack works, the wisdom of the adoption of the Emscher tank being amply confirmed by observations proving the superiority of this design of tank, both for sedimentation and sludge digestion, at every place where it was in use.

The fourth item is a matter of experiment, but by comparison it is reasonable to expect with dilute sewage, such as in America, a much better tank effluent than in the sewage of twice or three times more concentration in the German cities.

It is recognized that to obtain a satisfactory and ideal effluent supplementary treatment will ultimately be necessary. This must be obtained from percolating filters, the most rapidly operating and effective method known at present, or from some substitute that the sanitary world is awaiting with interest and expectancy.

Dilution with Rivers

If the effluents, under these conditions, from sewage works taking care of the drainage of millions of people, can go into the Rhine River without injury to that tooth-



Percolating Filters, Wilmersdorf, Germany.

some foodfish, the Rheinlacs, or Rhine salmon, how much more can the dilute sewage from Philadelphia works enter into the Delaware River, having only one-tithe of the population along its banks and having a volume from 50 per cent. to 100 per cent. more than the Rhine or of the Danube? The absence of fisheries or cities of any magnitude drawing water supplies from the river, emphasizes this advantage.

The observations confirm the judgment of the Chief Engineer, expressed plainly before the examination was made, that there should be adequate tank treatment and sludge disposal to improve the present condition of the rivers.

It is reasonable to conclude that the oxygen content of the Delaware River, as shown by observations taken in 1912-13, is reduced largely by floating particles, far more than would be the case were the solids intercepted.

If these be removed, the recovery of oxygen by the river between Philadelphia and cities lower down its course, in front of which cities are the proper places to observe conditions and give the river its rating, will be such as to place it within the range of any rational standard of dilution based upon the amount of saturation with dissolved oxygen, that in the wisdom of experienced sanitarians will be established.

The Pennypack sewage works, combining the best practice of Germany, England and America is up to date in design and construction, and should give excellent results.

Approximate Economies

The foregoing recommendations, some of which are contingent upon detailed study of the present plan, if applied and followed, should result in economies in many particulars, chief among which are those indicated below, with approximate estimates.

Description of Economical changes in present plan	Estimated Reductions	Estimated reduction in annual operating cost
Raising intercepting sewers	$1,080,000	—
Modifications of sections of intercepting sewers	627,000	—
Abandonment of tide gates, substituting dams	235,000	—
Reduction in cost of pumping station of Northwest Works by substituting siphon	400,000	—
Reduction in pumping cost of ditto	—	$90,000
Further reduction in cost of pumping station by installing latest improved pumps	128,000	—
Further reduction in operating cost due to ditto	—	62,000
Reduction in installation of pumps of latest improved patterns affecting building, etc., in the Southwest Works	382,000	—
Reduction in op rating cost of Southw.st Works due to ditto	—	130,000
Abandonment of two sludge steamers owing to knowledge of ability to dispose of sludge on land	400,000	—
Reduction in filling over works area, due to a suggested more economical design	500,000	—
Reduction in acr age of land to be acquired Northeast Works, 120 acres at $2,500	300,000	—
	$4,052,000	$282,000
Reduction in acreage of land to be acquired Southwest Works, 300 acres at $600	$180,000	—
Total	$4,232,000	$282,000
NOTE:—Changes determined upon the wisdom of which was confirmed by observations and inquiries abroad.		
Substitution of deep cross-town sewer for pumping station at Oregon avenue and Delaware River	2,200,000	—
Abandonment of final sedimentation after percolating filters	1,040,000	—
Reduction in annual charges due to ditto	—	145,000
Totals	$7,472,000	$427,000
NOTE: The reduction in operating cost represents an investment at 4 per cent. of	10,675,000	—
Total estimated economy by recent changes and changes recommended	$18,147,000	

PART II

INTRODUCTION

Pursuant to the study of the art of sewage disposal for large cities, carried on by the officials of the Bureau of Surveys during the past five years, and to the extensive experiments carried on at the Sewage Treatment Testing Station, covering a period of nearly two years, culminating in the publishing in 1911 of a complete report of its operation; and in connection with the preparation of a Report to embody a complete plan for the "Collection, Purification and Disposal of the Sewage of the entire City of Philadelphia," made obligatory in a decree issued by the State Commissioner of Health and by the Ordinance of July 20, 1907, and in order to observe progress in the Art, and the efficiency or inefficiency of various systems which have been in use for a period of years, it was determined, by the exercise of wise and excellent judgment on the part of the Director of the Department of Public Works and the Chief Engineer of the Bureau of Surveys, with the concurrence of His Honor, the Mayor of Philadelphia, that before issuing the final report upon this subject it would be well to inquire further into the existing conditions surrounding the sanitary disposal of sewage in European cities.

For that purpose, the Principal Assistant Engineer was chosen to undertake the mission, and was instructed to inquire into matters pertaining to the subject and to report his findings to the Department.

In compliance therewith, in connection with the execution of a special mission for His Honor, the Mayor; that of installing, at the International Building-Trades Exhibition at Leipzig, Germany, of an exhibit comprising examples of Comprehensive City Planning of the City of Philadelphia, the writer proceeded to Europe, and examined the

systems of sewage disposal, together with other matters appertaining thereto, in representative cities of Germany, Austria, Holland, Belgium, France and England.

STATUS OF THE ART.

The present status of the Art of Sewage Disposal is unsettled, and may be compared to the expectation, coupled with the hope and doubt, with which the medical world receives the statements and views the application of a new serum as a cure for a hitherto incurable or at least untractable disease, which has for generations been a great foe to longevity of life of the human race.

The cases are parallel, for the same animated discussions and arguments in favor or against, the introduction of chicanery, exaggerated claims which may not be borne out by results, failures or apparently brilliant successes are patent to both.

The necessity of considering the sanitary disposal of sewage a vital question is apparent, especially in Europe, owing to the density of population and the comparative smallness of natural water supplies; and, therefore, it has been considered necessary to establish Government Boards and Rivers Boards to supervise the streams, and to establish standards of purification to which the cities must conform. This sometimes places a heavy tax burden upon a community, which may by accident of location only be placed at this disadvantage.

Large sums of public funds have therefore been spent for the alleviation of nuisance caused by the discharge of untreated or insufficiently treated sewage into streams. The wisdom or unwisdom of the application of certain systems of treatment is conclusively proved by the results obtained; therefore, the cities of Europe are advantageous places for observation, and furnish object lessons whereby other communities may, by avoiding systems or combinations which

are there demonstrated to be ineffectual, save large sums of money, profiting by the costly experience of other cities.

The condition of the art, therefore, is one of expectancy Many systems and combinations have been tried, with varying success, most of them meeting a majority of their requirements in accordance with the standards set, but in many places visited it was stated by the managers that the plants are susceptible of decided improvement by alterations in methods of operation, frequently involving large additional expenditures.

These alterations can with difficulty be authorized until conditions become objectionable, and plants therefore must be operated without the application of new discoveries or improved devices, which would bring them to a higher state of efficiency, the aim of every sanitary engineer.

The amount of literature published upon the subject is voluminous and increasing, but the most effective textbook is that of examining at first hand, aided by judgment ripened by experience, the existing works in densely populated countries.

The advance made in the application of the art has been steady and positive, each step being taken only after lengthy experimental work upon new lines, coupled with experience in operation of existing works. But better results are looked for, and from the number and reputation of scientists engaged in the study of the question, changes, possibly revolutionary, are impending.

Occasionally revolutionary changes have survived the tests of time, but rarely.

The following statements may safely be made:

Sewage of exceptional concentration can be effectively treated, so as to secure a clear, ordorless, sparkling, nonputrescible effluent before discharging into a stream, the securing of which is a matter of cost, and is an economic as well as constructive problem.

Sludge resulting from sewage treatment can now be rendered innocuous, practically inodorous, wholly unobjectionable, after which it may be dealt with in various ways.

By certain combinations of treatment, desired results may be secured at a fraction of the cost of other recognized scientific methods of treatment in satisfactory operation. This offers an inviting prospect for investigation.

The securing of these results must be the chief aim of works managers, to do which it has frequently been determined to be economical, to turn into scrap everything which has been heretofore in use.

As a step in this direction, works in many places are being extended, so as to supplement tank treatment with bacterial beds or filters, which has been the most progressive recent occurrence in sewage disposal.

To take advantage of this experience means a saving of millions to Philadelphia in the construction of works.

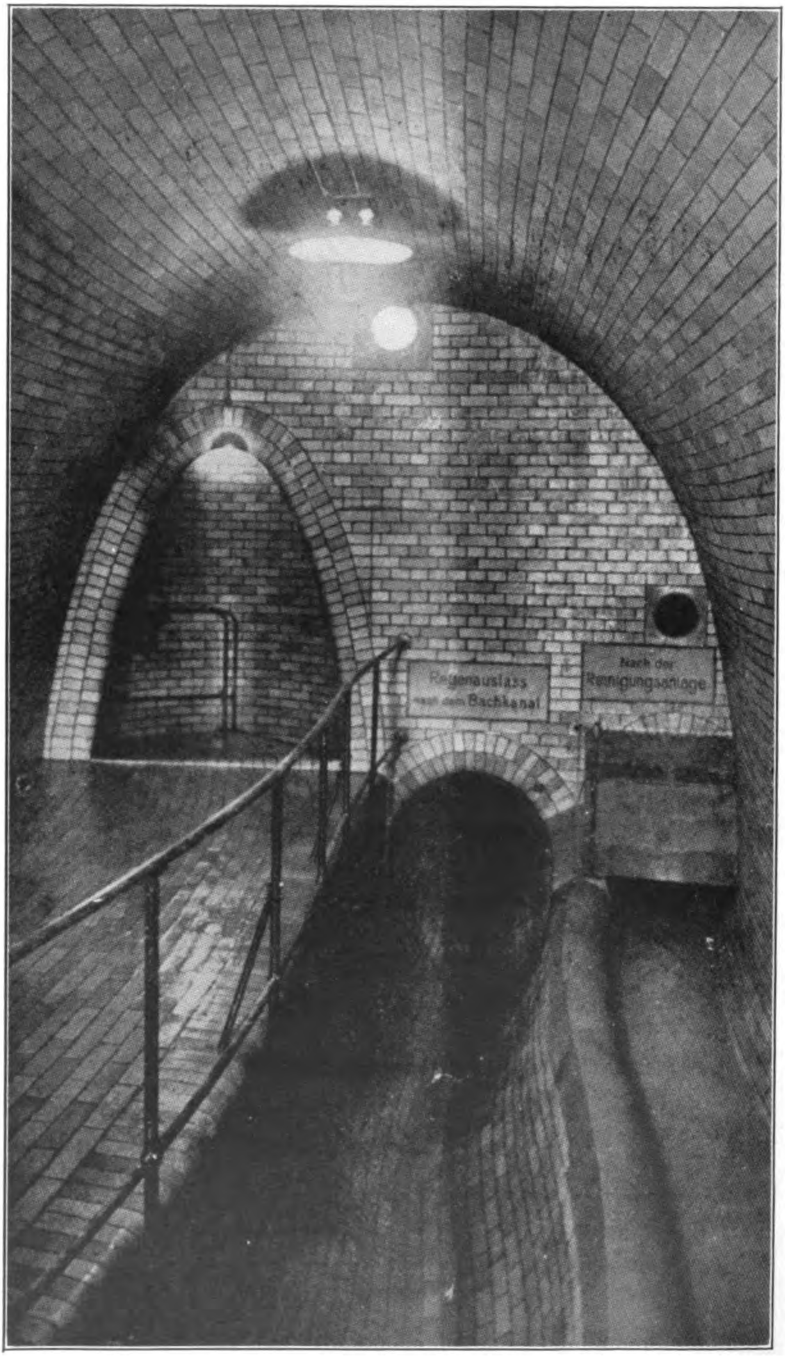
In the first instance, sewage farms were operated, and, excepting where prohibitive by reason of cost, have been abandoned.

Screening and tank treatment, sometimes coupled with land treatment, have been substituted in many instances.

At present, in many cases, the last mentioned has been found to be inadequate, and there has been added some form of bacterial bed treatment.

The disposal of sludge has been generally inadequate, and is now considered by many the most vital problem to be solved.

To protect the streams from nuisance, to conserve sources of water supply, to protect the health of the people, it is considered by sanitary engineers that sewage disposal is next in importance to water supply in the list of public works, and that the expenditure of large sums is justified, and as the art advances, additional sums to secure the best attainable result.



Typical Sewer Construction, Wiesbaden, Germany.

REASON FOR AND SCOPE OF THE INQUIRY

Inasmuch as the City of Philadelphia must eventually construct works to relieve the conditions in its various creeks, the Schuylkill River, and eventually the Delaware River, conditions which, as the population increases, must become more intolerable, and as, on account of the magnitude of the problem, it is desirable to have the most economical and efficient system obtainable, the inquiry was directed to secure information for future reference upon the following specific points:

> Canalization; Systems of Collection; Construction methods and materials; Comparison of screening devices; Screens versus Sedimentation; Ratios of Dilution; Relation of Disposal to Water Supply; Conditions governing adopted system of disposal; Comparison of areas required under different systems; Comparison of Results of Different Systems; Comparison of Results of Sludge Disposal; Pumping Systems and Economies; Cost Data.

RELATIVE VALUES OF THE INFORMATION SECURED FROM DIFFERENT COUNTRIES

Germany

The works examined in Germany were chiefly of value in the following particulars:

- Efficient scientific designing of canals, conduits and collecting sewers and appurtenances.
- Excellence in building materials and precision and care in construction.
- The development of screens and screening appliances to a high state of efficiency.
- The scientific design of tanks, and tank cleaning devices.

Their view, determining the proper relation of the municipality and the rivers in the work of treatment, having in mind the needs for other public works.

The object lesson of clean rivers, without nuisance, even with the discharge of partly treated sewage from dense populations into them.

The efficient treatment of sludge inodorously and proper disposal without nuisance.

Holland

Disadvantages of a low country, with drainage to canals.

Steps necessary to keep them sanitary.

Methods of construction under difficulties due to water.

Effective means of disposal of sewage under unusual conditions.

Relation of street grades to the drainage problem.

Relation of sewage disposal to harbor development.

France

Effect of construction of old-time methods of disposal.

Effect of a highly sanitary system of sewers in operation.

Experience with inverted siphons.

Efficiency of an extensive well constructed collecting system.

Magnitude of a change in methods of disposal in a large city.

Important proof of effectiveness of percolating filter in treating putrescible matter.

Belgium

The plight of large cities, when confronted with an urgent need of steps to establish a system of disposal.

England

More refined treatment necessary than in Germany on account of the small rivers.

Abandonment of land irrigation.

Ineffectiveness of a dilution standard for all cases.

Popularity and economy of machine distributors.

Sludge disposal still a vital problem.

Grease extraction possible under certain conditions.

Effects of indiscriminate drainage or the discharge of insufficiently treated sewage into small streams.

Recent improvements in pump design and construction.

Superiority of percolating filters over other bacterial treatment.

The use of oil engines in sewage works, also the gas explosion pump, promises great economy in pumping costs.

GERMAN WORKS COMPARED

The conditions respecting sewage disposal in Germany are generally as follows:

Class I. Those cities having available for disposal rivers of such capacity as to receive readily the effluent without nuisance.

Class II. Those cities which by reason of the small flow of the available rivers must carry treatment further than in Class I.

These may be subdivided into

(a) Works having screens and tank treatment.

(b) Works having tank treatment only.

CLASS I
Screens

City	Population	River		Sewage Flow in sec. m.	System	Solids removed	Remarks
		Name	Flow in sec. m.				
Hamburg	964,000	Elbe	High dilution	5	Rakes 15 mm.	20 cu. m.	Clean process
Dresden	560,000	Elbe	High dilution	1.05 to 1.16	Reinsch 2 mm.	64 per cent.	Clean process
Wiesbaden	108,000	Rhine	300	.3	Frankfurt rake 2 mm.	—	—
Köln	540,000	Rhine	900	.9	Sieves	—	—
Dusseldorf	400,000	Rhine	900	.7	Reinsch 2 mm.	12 cu m.	Passable

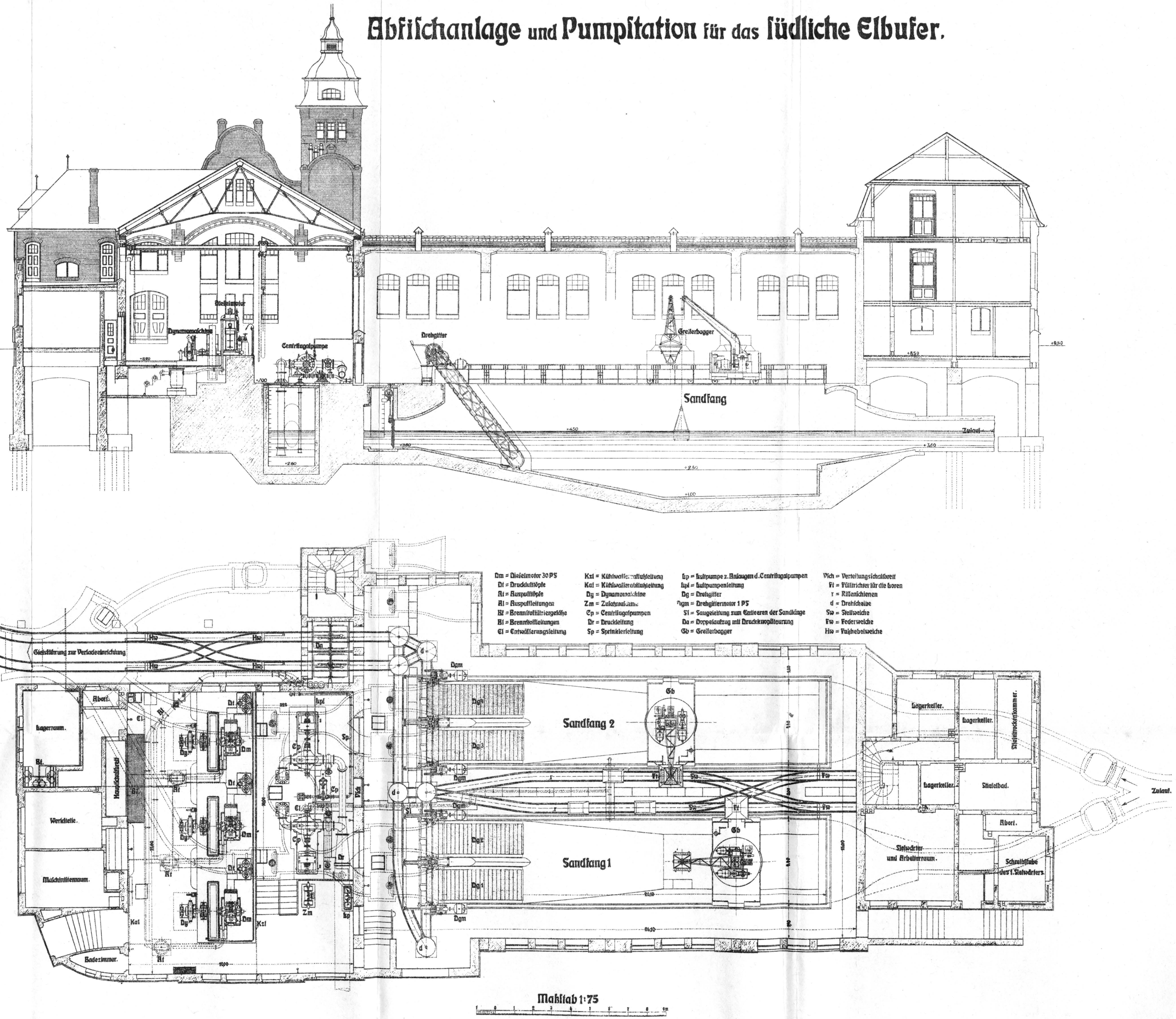
CLASS II A
Screens and Tanks

Leipzig	700,000	Elster	19	1.07	Screens 12 mm. and sedimentation		Poor effluent
Frankfurt on the Main	400,000	Main	40	1.05	Rakes and sedimentation	420 mg. L.	Excellent effluent
Elberfeld and Barmen	170,000 170,000	Wupper	3.6	0.64	Rakes 10 mm. and sedimentation	20 cu. m.	Medium results

CLASS II B
Tanks Only

City	Population	Solids		Flow of Sewage in Million gals. day	Per cent. removed	Remarks
		Sewage	Effluent			
Essen, N.	180,000	751	164	18,500,000	78	Effective
Essen, N. W.	92,000	898	160	12,700,000	83	Effective
Bochum	145,000	458	104	13,250,000	78	Effective
Recklinghausen	30,000	440	126	2,385,000	72	Effective

Abfischanlage und Pumpstation für das südliche Elbufer.



By reference to the tables it may be observed that in Class I, screening to remove the floating solids is considered sufficient. The comparatively large volume of the rivers and velocity prevent sludge deposits.

In Class II, the additional treatment is effected by the use of fine screens and tankage, or tanks alone.

The treatment is in no case carried further than tankage, with the exception of Wilmersdorf, where conditions require it. Coarse screens may be taken to be those of from 1 inch to 3 inches; fine, as being under 1 inch.

The coarse screens are principally used to protect the pumps, or where, by reason of the peculiarities of the tank system, it is undesirable to intercept the ordinary sized solids on the screens.

The fine screens are used to so reduce the organic floating matter as to lessen the burden of the rivers, in some cases being a finished treatment, in others preliminary to tankage.

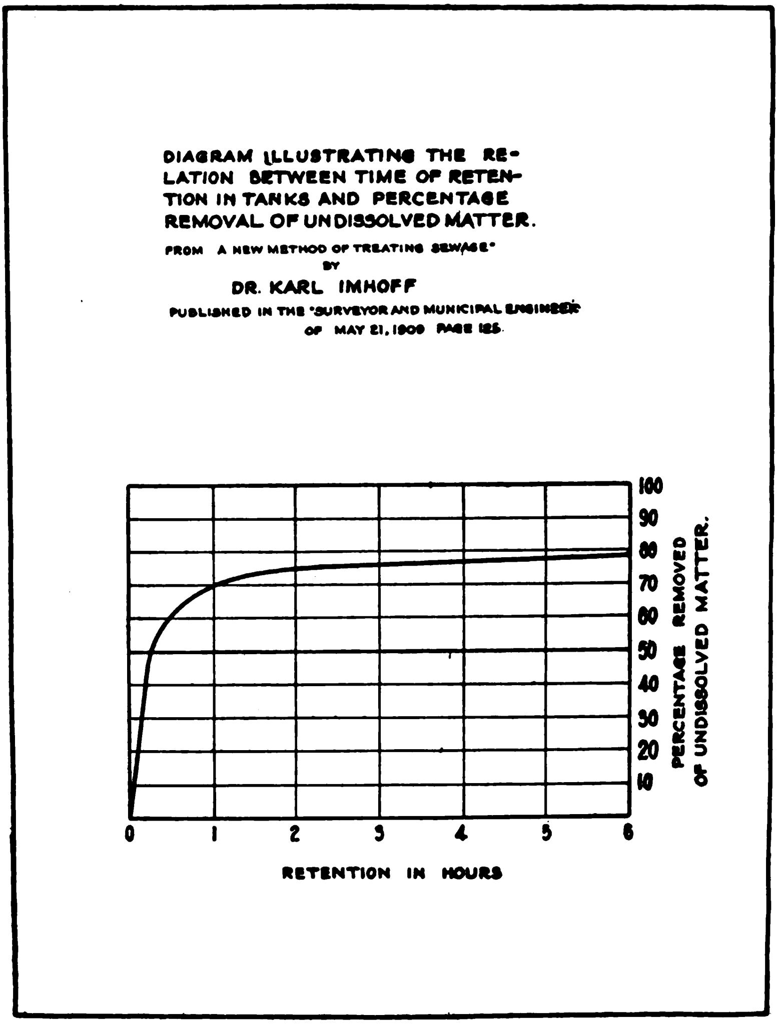
The different types of screens consist of "gitter" or rakes, of various bar spacing.

Of the fine screens, there are rakes over fixed screen bars; both rakes and bars in motion; brushes clearing moving bars; or fine slots on revolving discs, brush cleaned; bars travelling over drums, water cleaned, passing solids to crushing rolls.

For purposes of discussion, the word "screen" will be used for fine screens only, and "unscreened" for tankage treatment where fine screens are absent.

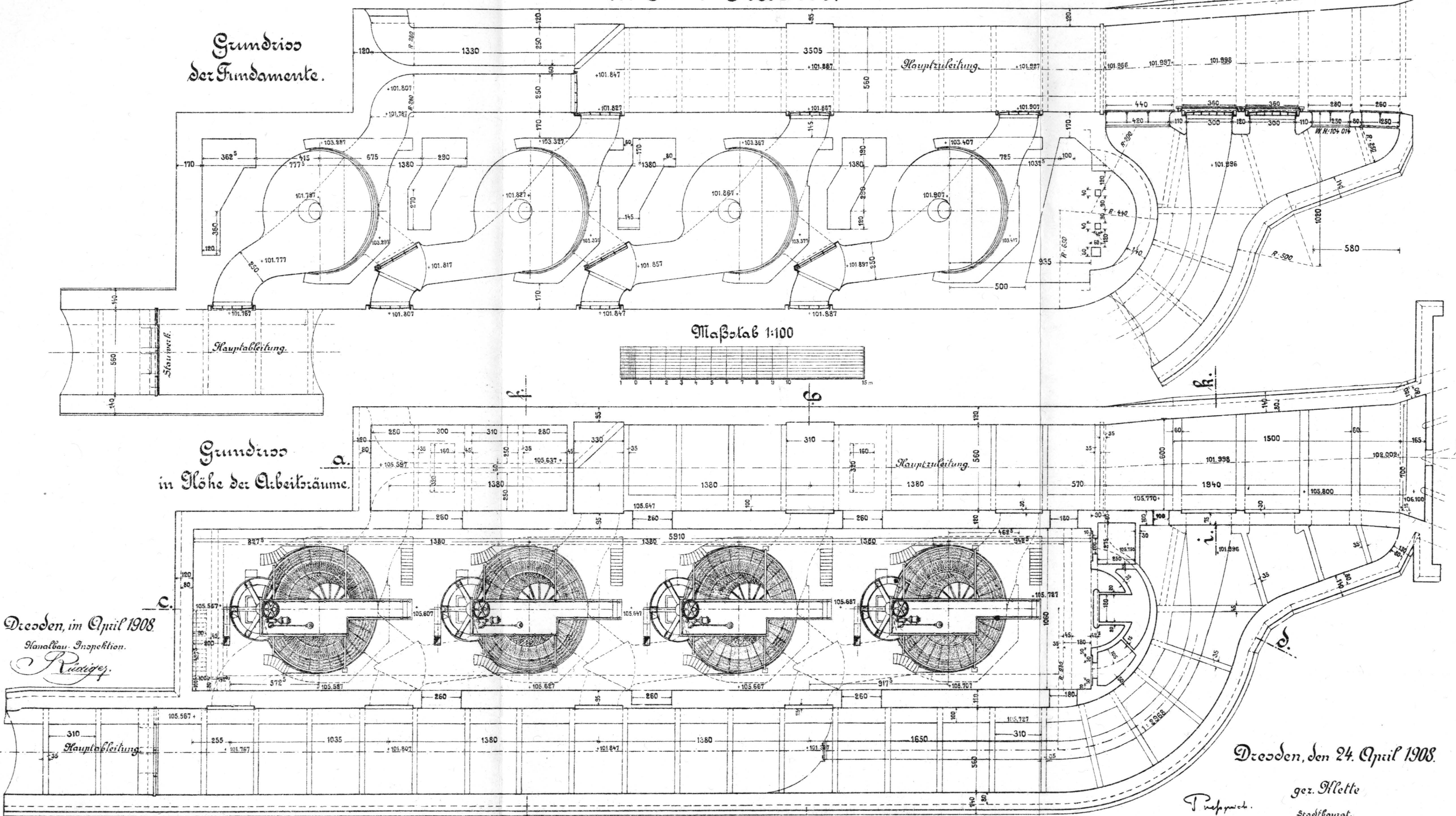
Screens vs. Tanks.

The following diagram gives the percentage removal of solids by tanks



Der Rat zu Dresden. Tiefbau-Amt.

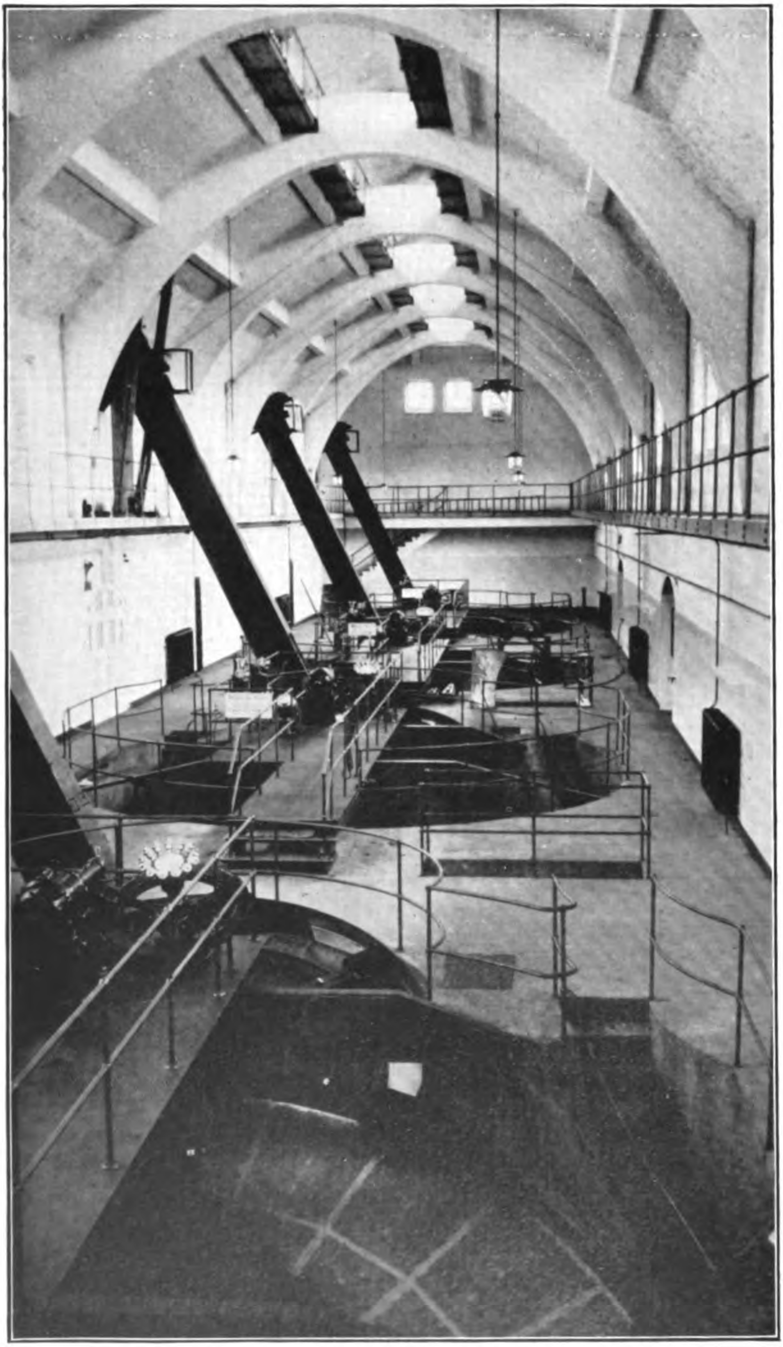
Anlage zur Reinigung der Abwässer mittels Separatorscheiben in Flur Kaditz.



Dresden, im April 1908.
Kanalbau-Inspektion.
Rüdiger.

Dresden, den 24. April 1908.
gez. Klette
Stadtbaurat,
Kgl. Oberbaurat.

Zu A. R. L. 1. III. A.
C. Walther.



Screen Room, Sewage Disposal Works, Dresden, Germany.

The quantities of solid matter removed from sewage by screens are shown upon table Class I. While the data is not in such form as to be readily comparable with tankage systems, it can well be asserted that of all the screens in use that at Dresden gives the highest efficiency, which is 64 per cent. removal; others are less than one-half this, as a matter of judgment.

By comparison with table Class II-b for tankage only and with diagram, it is apparent that tankage treatment is more effective in the removal of solids than is screening.

In addition, tankage treatment is more flexible, in that longer storage will remove more solids.

The argument is advanced that screens take less room, can be confined to a building, while tanks must be subject to climatic changes and variations in character of sewage, also that more land is required.

From observations, it would appear that the extra cost of land is more than offset by first cost and operating cost of screening machinery.

Where, therefore, the flow in a river is sufficient to afford proper dilution for the sewage and screening alone is necessary, as at Hamburg, the use of fine screens is of advantage owing to the ease of handling the screening, the ability to confine the treatment to a building, which may be set in a populous section without nuisance, and thereby avoid the cost of long conduits and large areas for sludge storage.

Where other conditions prevail, the rivers being inadequate to furnish proper dilution, tankage treatment appears to be advantageous in place of screens.

Dilution

In German cities the available rivers are looked upon as the legitimate places of disposal of liquid wastes, after sufficient treatment has been applied, so that when discharged therein, with sufficient diluting water, the streams

themselves are expected to accomplish the continuation of the treatment and oxidize the organic matters.

It is considered improvident to carry treatment further than is required by the local conditions, because of the needs for appropriations to other municipal purposes.

It is apparent from observation that no nuisance to sight and smell results from screening sewage alone, or from tank treatment alone, when after discharged the velocities in the streams are such as to prevent sludge deposits.

With good velocities, oxygen absorption or aeration is accomplished, and fish life is not menaced. In addition, water supplies from driven wells adjacent to the rivers are not menaced, therefore the German view is that dilution in proper quantity is the only logical system of ultimate sewage disposal.

Sewage Farms

Where by the proximity of streams so inadequate as to furnish practically no dilution, it is impracticable to use them for disposal, as is the case of the Spree at Berlin, and where extensive areas favorable for land treatment are available, they are accepted, but not from choice, because to change the system would be too revolutionary.

Water Supply and Sewage

The cities of Germany are concentrated in area, populous, from 100,000 to 1,000,000 (Berlin, over 2,250,00), are situated on rivers of sizes varying from the equivalent of little Tacony Creek to three-fourths the size of the Delaware River, usually having considerable velocity.

After screening or screening and settling, the sewage is discharged therein, apparently, without nuisance in the larger rivers. The cities discharging sewage into the rivers frequently take the water supply from points below their own points of discharge from driven wells in the sandy

[illegible] v. Bogdan Gisevius, Berlin W. Bülowstr. 66.

Covered Sedimentation Tanks, Frankfurt a/Main.

soil adjacent to the rivers, as in the case of Elberfeld, Altona and others.

The low death rate from typhoid fever as compared to that in our American cities is a sufficient answer to any objection to the practice.

No case was found where complaint has been entered against an adjacent city for the discharge of sewage into a river from which water must be taken for a water supply.

Rivers Boards and Requirements

The Rivers Boards are clothed with sufficient authority to regulate a disposal works, and do regulate the treatment necessary to secure a proper effluent, but as no emergency has arisen calling for drastic action, fine screening or screening and tankage are acceptable in most cases, the screening to extend to from 4 to 6 times dry weather flow.

In the case of Wilmersdorf, the effluent comprises the whole flow of a canal emptying into the Spree; therefore the effluent must be non-putrescible.

Sludge Disposal

Sludge disposal consists of lagooning on land, selling or giving away to farmers, burning in a destructor, or, after drying, using to fill in low areas.

Systems Compared

As the sludge is in most cases only screenings, it is fresh, has good manurial qualities, and if sold or given to farmers, it is effectively disposed of without nuisance.

Where tankage is resorted to, notably at Frankfurt a/M., and Essen, the resulting sludge is in the former case dried in centrifugal machines, further dried by heat, then used for fuel to develop electricity; effective, without much nuisance. In the latter case, the sludge is made inodorous and innocuous by long tank digestion, is lagooned upon underdrained

beds, dries in from 5 to 12 days, is hauled upon low land, to make up hollows, where not removed without expense by farmers. This method is entirely devoid of nuisance, and is accomplished at low operating cost, and on small acreage.

Trend of New Designs

The trend of new designs or where extensions must be made to old works is divided between fine screening and additional tankage.

In one case, Düsseldorf, tanks were determined upon for extension works after exhaustive tests and calculations as being more economical than screens, and the type chosen was the Emscher, on account of efficient sludge disposal.

General Conclusions

For the larger rivers in Germany, fine screening for the present appears to be sufficient.

Where screening is resorted to, proposed extensions contemplated in some instances, as at Hamburg, tanks and percolating filters, in other, tanks or finer screens.

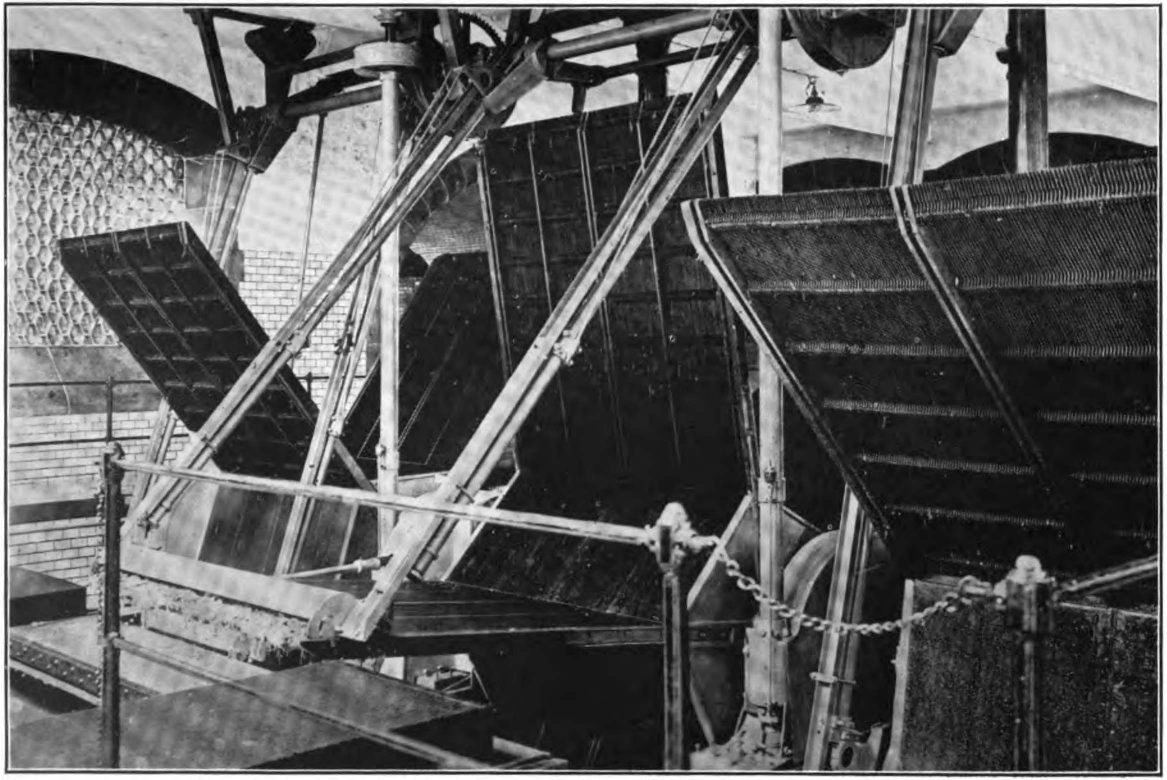
It is recognized that eventually more complete treatment will be required, the time for which will be determined by the condition of the rivers in each case.

Wornout plants are adding more modern screening machinery.

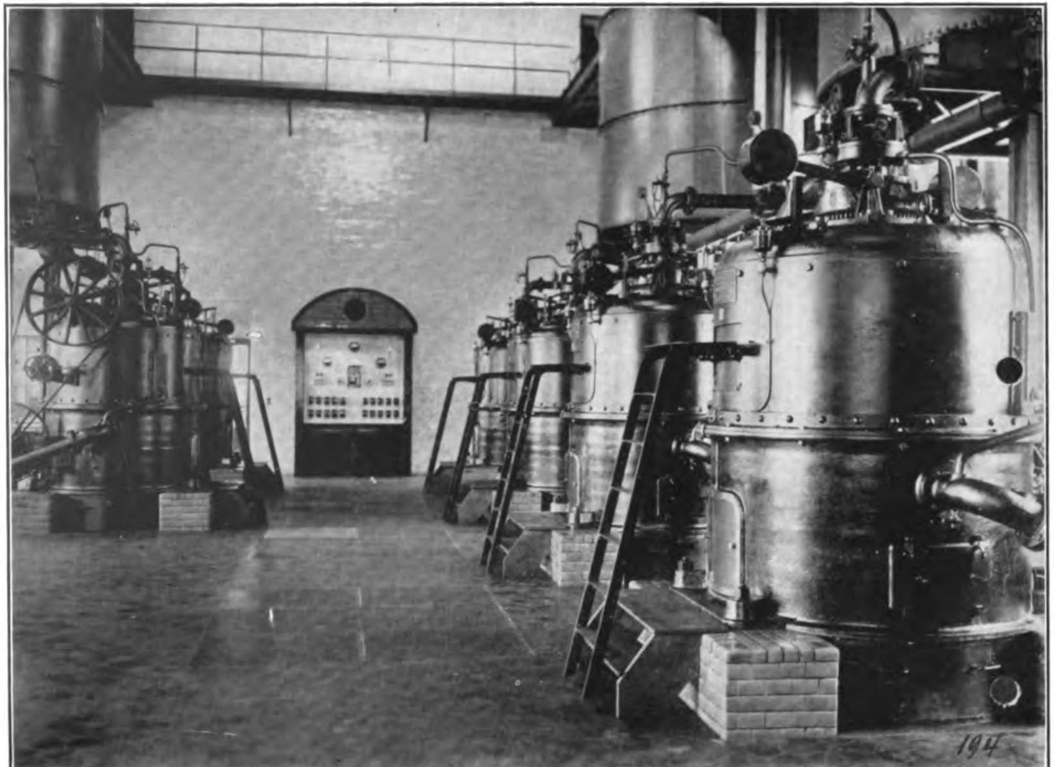
The cleanest, most economical screen is the Reinsch screen used in Dresden, with the Frankfurt a/M. type of 5 vane rake a close second.

Screens, however effective in many cases, cannot compete in efficiency with properly designed tanks.

The sludge digestion in an Emscher type tank, whether from sewage composed entirely of domestic wastes or of manufacturing wastes predominating, is most effectual, and after drying is without nuisance, comprises smaller bulk



Fine Screens or Rakes at Frankfurt a/Main.



Centrifugal Sludge Dryers, Frankfurt a/Main.

than other methods, and may be used for filling, manure or fuel.

The drying by centrifugal machine and passage through heated tunnel, then burning under boilers to produce electricity, as as Frankfurt a/M., has its advantages, but for cheapness does not compare with the Emscher sludge, which also may be used for fuel.

The designing of collector systems is placed upon a scientific basis in German practice, and the materials and workmanship used in construction are superfine.

The Philadelphia system of design is equally scientific, but details are not developed to such length, nor can construction compare in exactness in our case, although probably equal to all America's requirements.

The systems in vogue are object lessons in showing the ability to clarify sewage and dispose of sludge of large populous cities upon a comparatively small area, without nuisance, as evidenced by private building operations adjacent to existing works.

The separate system of sewers has no place in a modern collection system, except in very special cases.

The wisdom of proportioning the work of sewage treatment and water supply treatment, and making a river be its own arbiter in the requirements of treatment.

The fallacy of constructing at once a sewage disposal system to meet the optimum requirement, and the advisability of proceeding towards this optimum by well defined steps, the time for extensions being determined by existing local conditions.

FRENCH WORKS

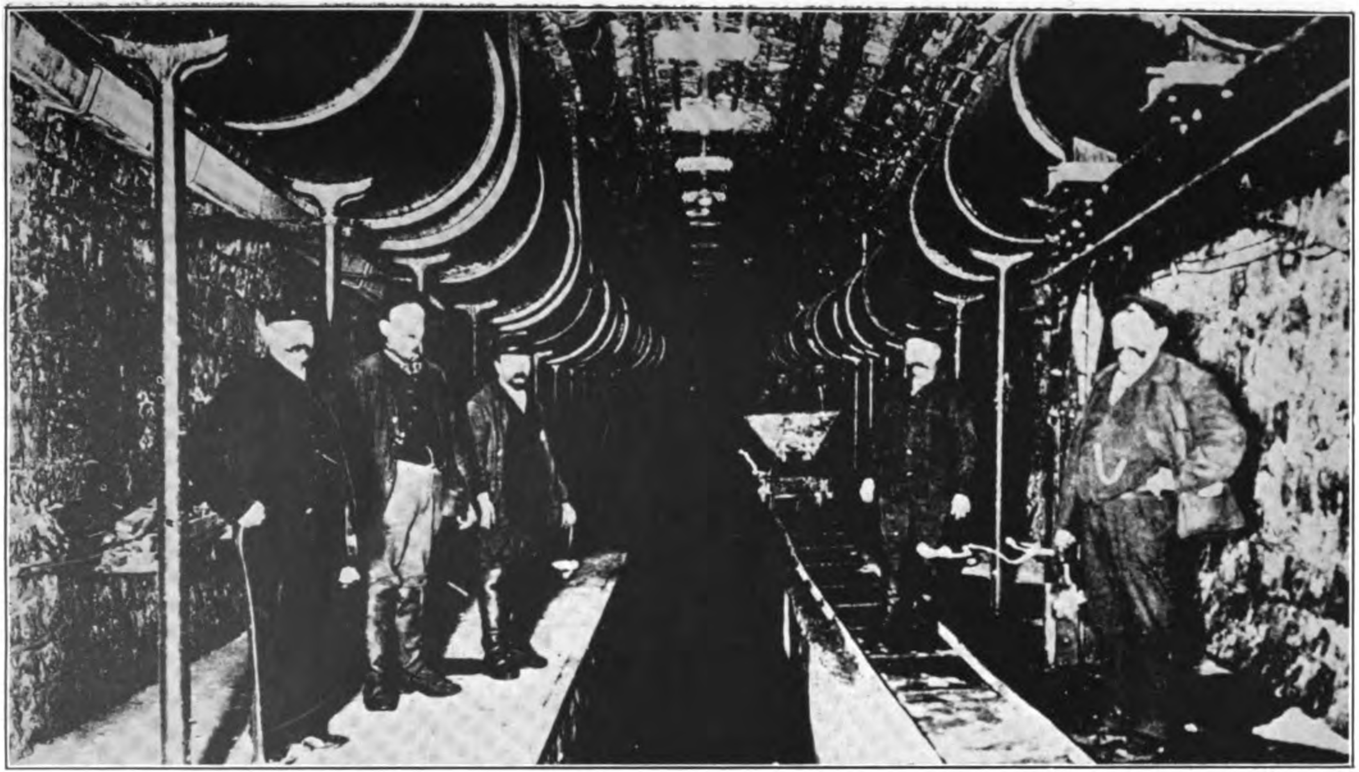
The sewers of Paris are chiefly valuable in giving an object lesson in construction.

The sewers in their various ramifications form one of the sights of Paris, visitors being taken through in boats or cars electrically propelled.

The conduits are more than sewers, the drainage being carried in a central depressed channel, and the additional space being utilized for water, gas, lighting and telegraph cables, and other underground structures. The material is concrete.

The collectors on each side of the Seine are effective in relieving it of pollution, and have overflows at intervals, admitting of the discharge of storm water even during high stages of the river.

The sewage is at places carried by siphons under the river and under several valleys and streams in its progress toward the treatment areas, as shown in accompanying table. Extensions of the main collectors are under way, involving the construction of many miles of large conduits. The sewage collected is taken 30 or more kilos down the Seine to various sewage farm areas where broad land irrigation is practiced.



View in Paris Main Sewer showing Cunette for Sewage and Pipes in Gallery.

SEWAGE SIPHONS (INVERTED)

Paris Main Drainage

Location	Built	No. Conduits	Diams.	Length	Depth	Elevation Upper	Elevation Lower
Alma	1868	2	1 m.	Under Seine	3.45 m.	—	—
Isle of Paris	1891	4	.4 & .5 m.	Seine, 2 branches	7.68 m.	30.46 m.	28.12
Pont Moreland	1879	2	.6 m.	Seine	—	—	—
Canal St. Martin	1890	2	.6 m.	Canal	—	—	—
Paris Outfall		Siphons, total length, 7,650 m. = 4¾ miles.					
Clichy	—	—	2.30 m.	463 m.	24 m.	—	—
A'Herblay	—	2	1 m.	463.5	—	—	—
Chennevieres	—	1	2 m.	2 kilos	13 m.	50 m.	48 m.
L'Oise	—	1	2 m.	276.42 m.	25	46 m.	44 m.
Maurecourt	—	1	2 m.	1022 m.			
Argenteuil	—	2	1.8 m.	2½ kilos	—	—	—

Grades of Sewers—0.6 m. diam. 1.50 m. per kilo.
2.0 m. diam. .95 m. per kilo.
3.0 m. diam. .50 m. per kilo.
4.0 m. diam. .30 m. per kilo.

For some years an experimental testing stating has been in operation, with large volumes of typical sewage.

As an evidence of the effect of various stages of a treatment upon sewage, there is given below a table.

TABLE.

ILLUSTRATING EFFECT OF DIFFERENT PHASES OF TREATMENT AT THE EXPERIMENTAL STATION IN PARIS

Sewage	Matter in Suspension	Oxygen Absorbed in 4 Hours	Ammonia	Nitrates
Ivry	900	31	17	—
Messly (Testing Sta.)	316	30.2	18.7	—
Septic Tanks	87	28.2	19.4	—
Bacteria Beds	6	5.9	7.8	40.5

NOTE:—"The co-efficient of clarification 99.3 per cent. The co-efficient of purification, calculated according to usage, after oxidization is 81 per cent. The imputrescibility is absolute."

From this it will be seen that the putrescible matter in sewage has undergone no change through the tanks.

The major portion of the work has been done in the percolating filter, as shown by a purification of 79 per cent. and a nitrate formation of 40.5.

In the contemplated project for a new disposal system, tankage treatment and percolating filters are projected.

In addition to Paris, among French-speaking cities may be included Brussels.

The construction follows closely the Paris sections of sewers, mostly old works.

The disposal is into the river Senne, a stream about like Jones Falls, Baltimore, covered over through the center of the city.

The sewage is intercepted on both sides of the covered river and delivered about 7 kilos below the city.

Treatment includes only coarse screening to protect the pumps.

New treatment works are projected, for which a preliminary report has been made by Mr. Watson, of Birmingham, England.

In both cases the trend of design for extensions will no doubt include percolating filters.

General Conclusions

Much of the cleanliness of a system depends upon the proper design and the securing of smooth work, especially in inverts.

In a large city, combining city utilities, and placing them in large conduits, may be economical, even though first cost may be large, when the saving of street paving and lack of interference with traffic is taken into consideration.

Sewage may be taken for long distances through properly constructed conduits which do not permit of deposits without becoming septic or objectionable to the senses.

Siphons of large size and considerable length may conveniently be used in a system without trouble in maintenance.

Large cities, finding that an existing system has its limitations, can best conserve their resources by conservative recommendations for improvement, following exhaustive experiment.

Large cities, with no treatment or inadequate treatment, in order to maintain a proper position must take steps to free the rivers from pollution by establishing or improving works.

In designing improved works under above conditions, the tendency is toward percolating filters to reduce putrescible matter.

DUTCH WORKS

The condition throughout Holland, and including Antwerp in Belgium, is that of frequent canals intersecting the cities with streets on both sides.

In all cases discharge through sluices to the sea must be resorted to.

To create velocity, a sluice is opened admitting water to a main canal to furnish the proper dilution, and the canals allowed to drain to the sea at low tide through other sluices.

Abuse of drainage privileges in the principal cities for many years by dumping raw sewage into the canals, has made them, in some cases, boiling septic tanks, foul smelling and floating scum channels.

New works comprising interceptors along each bank of a canal are being constructed, under difficult conditions, due to mud foundation and water infiltration.

These interceptors will be carried to pumping stations and the sewage pumped into the sea, and will no doubt result in a bettering of the sanitary condition of the principal canals in Amsterdam, Hague, Rotterdam and Antwerp.

Where sea disposal can be had, no other treatment is required.

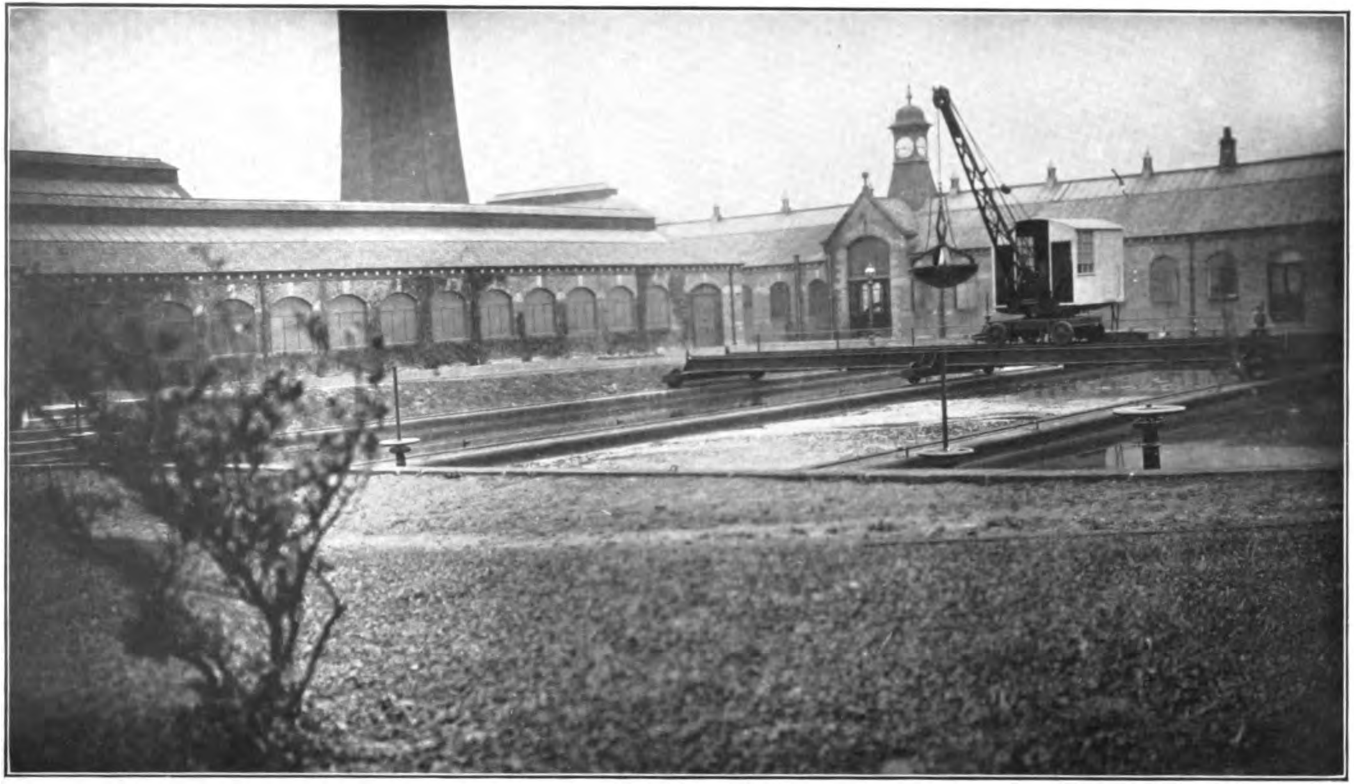
General Conclusions

Cities so situated as to require development on grades lower than high water of neighboring seas may be properly maintained and properly drained, even with such grades.

The modern high-powered pump for low lifts can readily be installed in a compact building, and can take care of drainage and storm water without difficulty at much less than the cost of filling in the land, so as to secure drainage by gravity at all stages of the water.

Effective sewers adjacent to canals can readily be built water tight of concrete sections, with asphalt grouted joints.

The maintenance of canals to receive a storage of storm water need not necessarily be insanitary, as shown by the conditions in the König's Allée at Düsseldorf; on the other



Grit Chamber, Huddersfield, England.

hand, they may be made most attractive and artistic parts of the park systems.

ENGLISH WORKS

Without repeating the various acts of Parliament bearing upon the question of sanitation, it may be stated broadly that the small sizes of the rivers upon which many of the large manufacturing cities are situated require extreme measures to prevent them from becoming plague spots. They are scarcely larger than little Tacony, Pennypack or Wissahickon Creeks, sometimes much smaller.

They are for the most part foul, ill-smelling streams, due to individual factory wastes or unauthorized town drainage discharged into them.

What the streams would be without the treatment of the sewage from the large cities I hesitate to assert, but even with this, they are in a condition from a sanitary standpoint below that of the sewage effluents discharged into them.

For this reason, and on account of a number of cities discharging into the same stream, dilution data or dissolved oxygen content is useless to the authorities, and is not observed by the works managers.

The streams are much smaller than in Germany, with the exception of those at Essen, Elberfeld and Munich, which explains the necessity of carrying treatment further in England than in Germany.

The collecting systems of the manufacturing cities of England are upon the combined plan, the system usually old and a conglomeration of designs. Usually the outfall sewer and works are under the control of officials other than the City Engineer. The data obtained, therefore, is largely confined to works.

Local Conditions

The cities are usually concentrated in area, with large outlying sections favorable for disposal works, usually built

from 3 to 5 miles from the cities. Some present very hilly features, others flat, but all capable of transporting most of the sewage to the works by gravity. Some must pump to the tanks at the works, others more favorably situated have gravity transit through the works.

Early Conditions

In the earlier stages of treatment, some 30 years ago, broad land irrigation was much in use, but has been almost completely abandoned.

The next step was some form of tank treatment preceded by coarse screening. This has been carried to its ultimate conclusion, and when extensions were necessary further treatment was projected.

In many of the works this second rearrangement is now under construction, and not before it was needed, as shown by the rivers.

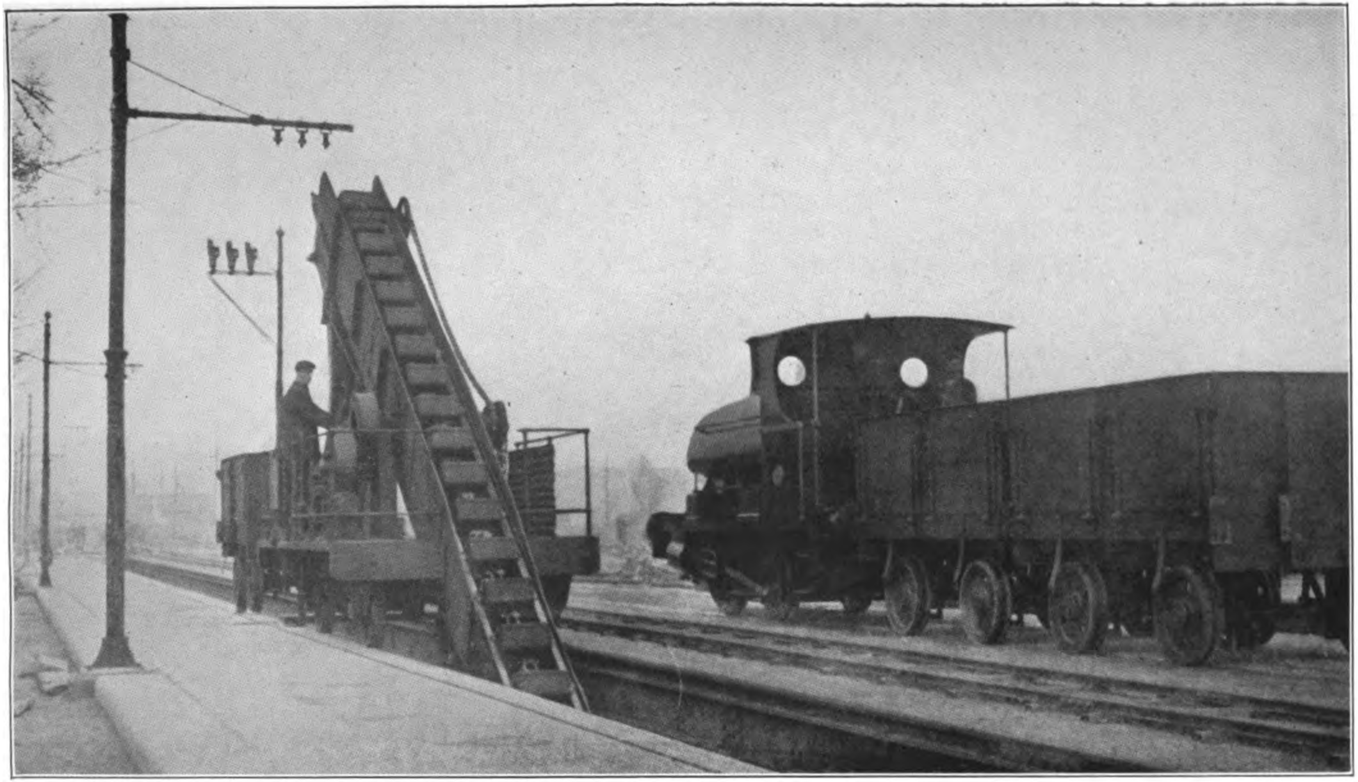
Classes and Transition

The works in England are so various in their combinations that it is difficult to place more than two in any one class. They may generally be described as having screens, either coarse, fine or both, grit or detritus chambers, septic tanks or sedimentation tanks, with effluent to stream.

The transition stage appears to be reached, already completed in some of the smaller works, and two of the larger works, of adding to tank treatment the bacterial treatment, either in the form of contact beds or percolating filters.

River Board Requirements

These changes have been brought about by the Rivers Boards increased requirements, in attempting, as far as possible, to conform to the standards for dilution as set by the Royal Sewage Commission, 8th Report.



Electrically Operated Dredger, Saltley, Birmingham, England.

Standards of the Royal Commission

"The effluent should not contain more than 3 parts of suspended matter per 100,000, and that, including its suspended matters, it should not take up more than two parts of dissolved oxygen per 100,000 in 5 days at 65 degrees F."

"A standard of 6 parts of suspended matter per 100,000 should be adopted where the dilution, while not less than 150, does not exceed 300 volumes."

"Where the dilution is more than 300 volumes, but less than 500, a standard of 15 parts per 100,000 might be permissible."

"Where the dilution is over 500 volumes, and no treatment is considered necessary, the standard would, of course, be in abeyance."

Tankage systems compared

The tankage portion of systems can best be compared from the table below:

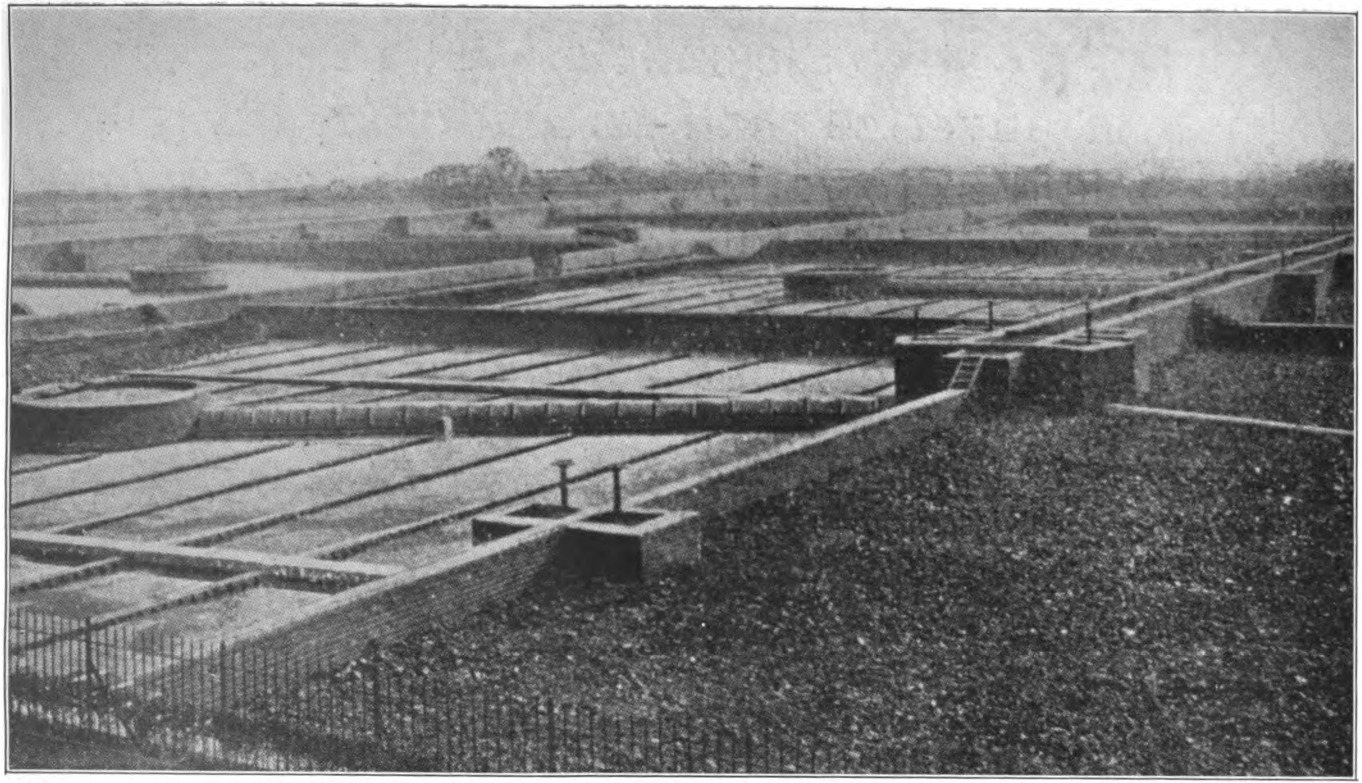
TANKAGE SYSTEM

City	Tributary Population	Raw sewage parts per million suspended matter	Tank treatment	Chemical	Effluent parts per million suspended matter	Percentage removal	Remarks
London Crossness	2,700,000	498	Chem. prec.	Lime	100	80	Detritus tanks as preliminary
Birmingham	950,000	577	Septic	No	217	62	
Leeds	475,000	609	Septic	Lime	85	86	
Sheffield	480,000	481	Sedimentation	No	142	70	
Salford	250,000	400	Chem. prec.	Lime	29	92	
Manchester	240,000	308	Chem. prec.	Lime	55	83	

Bacterial filters' efficiency appears below:

BACTERIAL FILTERS

City	Population	Kind of Bed	Rate gals. per sq. yd.	Influent parts per million	Effluent parts per million	Percentage Removal
Manchester	240,000	Contact	—	54	23	57
Sheffield	480,000	Contact	—	142	85	75
				Oxygen	absorbed	—
Birmingham	950,000	Percolating	166	12.006	1.62	86
Huddersfield	110,000	Percolating	132	4.96	1.01	80
Salford	250,000	Percolating	280	8.3	0.82	90
York	90,000	Percolating	143	8.0	0.50	88



Sheffield Corporation Sewage Works, Bacteria Beds.

Machine Distributor on Percolating Filter, Bolton, England.

Percolating Filters, Huddersfield, England.

Bacterial Filters and Tankage Compared

The great advantage of applying the supplementary treatment after tankage treatment is sufficiently well shown by the work of the bacterial filter, set forth in the above table.

Distribution Systems

The variety in methods of distribution upon bacterial filters is shown by the following table:

DISTRIBUTION ON PERCOLATING FILTERS

City	Acres of Filters	Method of Distribution	Depth in feet	Amount per cu. yd.	Remarks
Birmingham	31	Nozzles	6	90 gals.	Effective
Salford	8	Nozzles	5	280 gals.	Effective
Blackburn	2½	Rotating arms	9	100 gals.	Effective
Huddersfield	3	Rotating arms	7	100 gals.	Effective
Accrington	—	Rotating arms	9		
Bolton	2	Fidian machine	6		
Bolton	2	Rotating arms	6		

Sludge Disposal

The methods of sludge disposal are as various as the number of plants, dependent upon the ideas of the managers, the local conditions or the accidents of chance.

They may be described as deep lagooning, shallow lagooning, trench burying, towing to sea, spreading on fields from irrigating canals, towing by canal boats to farmers, extracting grease and drying for fuel, carbonizing and bye-product recovery, transportation by train to low land.

The following table gives particulars:

SLUDGE

City	Treatment	Sludge Production per week in tons	Method of Disposal	Remarks
Birmingham	Septic and Percolating	8190	Underdrained lagoons	Ineffective
Salford	ditto	1800	Steamer to sea	Effective
Bolton	ditto	1250	Press, dry and sell	Effective
Bradford	Sep. and Chem.	550	Grease recovery	Profitable
Manchester	Sep. and Contact		Steamer to sea	Effective
Accrington	Sep. and Per.		Canal boats to farms	Effective
Blackburn	ditto		Irrigation on fields	Effective

General Conclusions

The tank treatment alone is not sufficient to prevent extreme pollution of the small rivers.

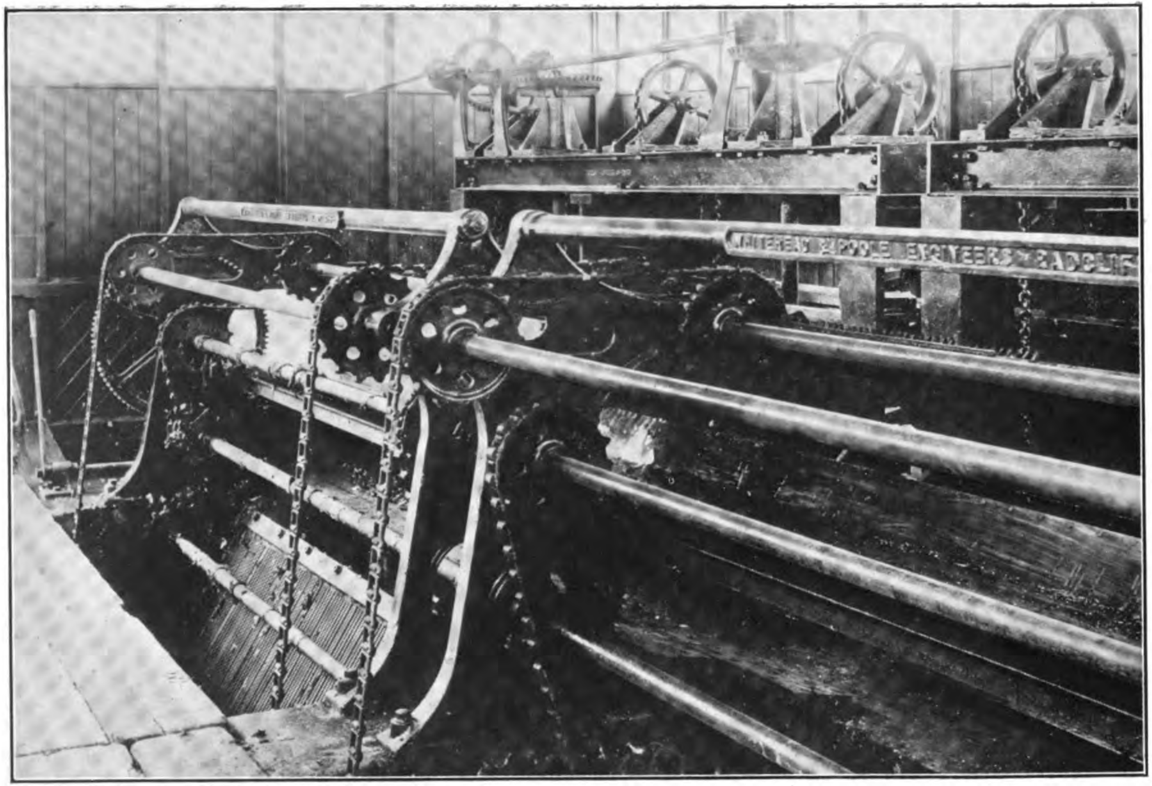
The establishment of a dilution standard is not feasible to maintain, as, by accident of location, certain cities have a dilution that is nil.

The addition of bacterial treatment to tank treatment will greatly improve the effluents. Existing plants are to a great extent undergoing reconstruction in this particular, There appears to be no definite relation in existing works between the amount of sewage to be treated and the area required for such treatment.

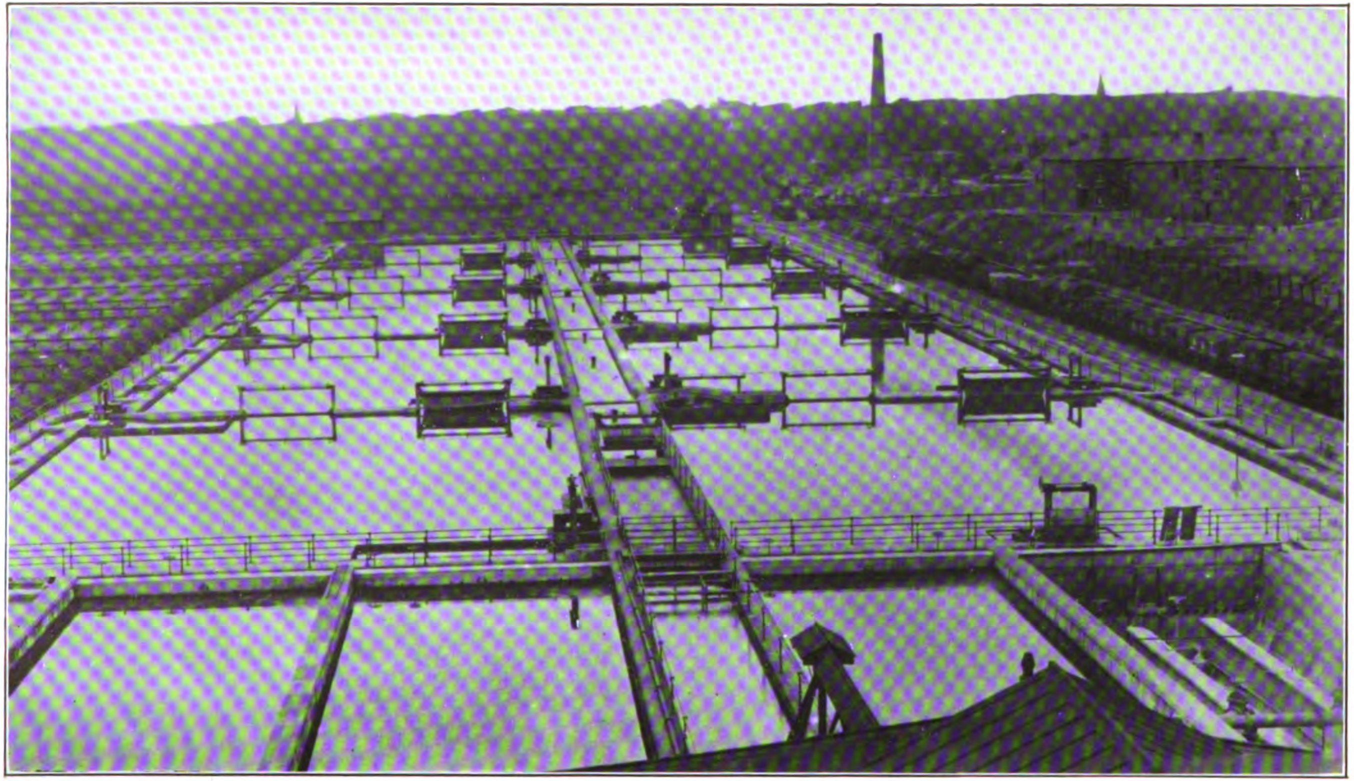
On bacterial beds, under condition of climate existing, the machine distributor gives better distribution than fixed sprays, but is less flexible and can probably not treat as much sewage as the latter on equal areas.

The abandonment of land irrigation wherever it has been in use on account of nuisances created. The use of stone as a medium for percolating filters at greater cost than slag is favored on account of its long life.

To reduce the fly nuisance, brick or solid enclosing walls for a percolating filter, with a fine medium on the surface of the filter, is advocated, the wisdom of which appears to be borne out by examination.



Screen in use, Bolton, England.



Salford Sewage Works. General view of Settling Tanks and Percolating Filters.

The proper disposal of sludge is a vital problem, and is frequently the only serious defect in an otherwise efficient works.

Large lagoons of sludge, well digested, are not very much of a nuisance, though extravagant of land and uncertain in their action.

That where the sewage is rich in grease content, and only under these conditions, bye-products sufficient to warrant the expense of plant are obtained, sometimes at a profit.

Where location is favorable, sludge may be sold for manure at about the expense of handling.

All systems of disposal of sludge, except that of carrying to sea, as in the case of London, Manchester and Salford, are haphazard. The problem elsewhere has not been solved.

Percolating filters have a decided lead in smaller area and maintenance charges over contact beds.

Some engineers are hopeful and express their confidence in the belief that a method of removing putrescible matter to supersede the percolating filter is capable of and will be developed. Doubts of the efficiency of applying the system of percolating filters to extremely large areas have been expressed by those who, by reason of long experience with them, are best competent to form a judgement.

That notwithstanding the increase in the number of treatment works, the rivers, by reason of receiving a number of individual factory wastes and those from other sources not accessible to sewers, are foul, ill smelling, scum and sludge bearing streams, worse, in most cases, in composition than the effluents which empty into them.

Dilution data, as represented by the dissolved oxygen content, are therefore of no value, and hence not observed.

Differences of opinion and criticisms by engineers of other works than their own proved a valuable aid in discriminating between the apparent and actual results

achieved. The results obtained after new works are placed in service will give valuable data to the sanitary engineer.

GERMAN AND ENGLISH WORKS COMPARED

The types of works in Germany and England are governed by the volume and velocities in the rivers. In Germany, where the volume is adequate, screening only is carried on; where the volumes are very small, screening and tankage.

Owing to the small average sizes of the rivers of England, and their pollution, a greater degree of treatment is there necessary.

The best information upon screens and tank treatment is obtainable in Germany; upon bacterial treatment, or oxidizing treatment, in England.

As to sludge disposal, with but two exceptions (Essen and Frankfurt a/M.) they are as badly off for a solution in Germany as in England, and appear to be groping.

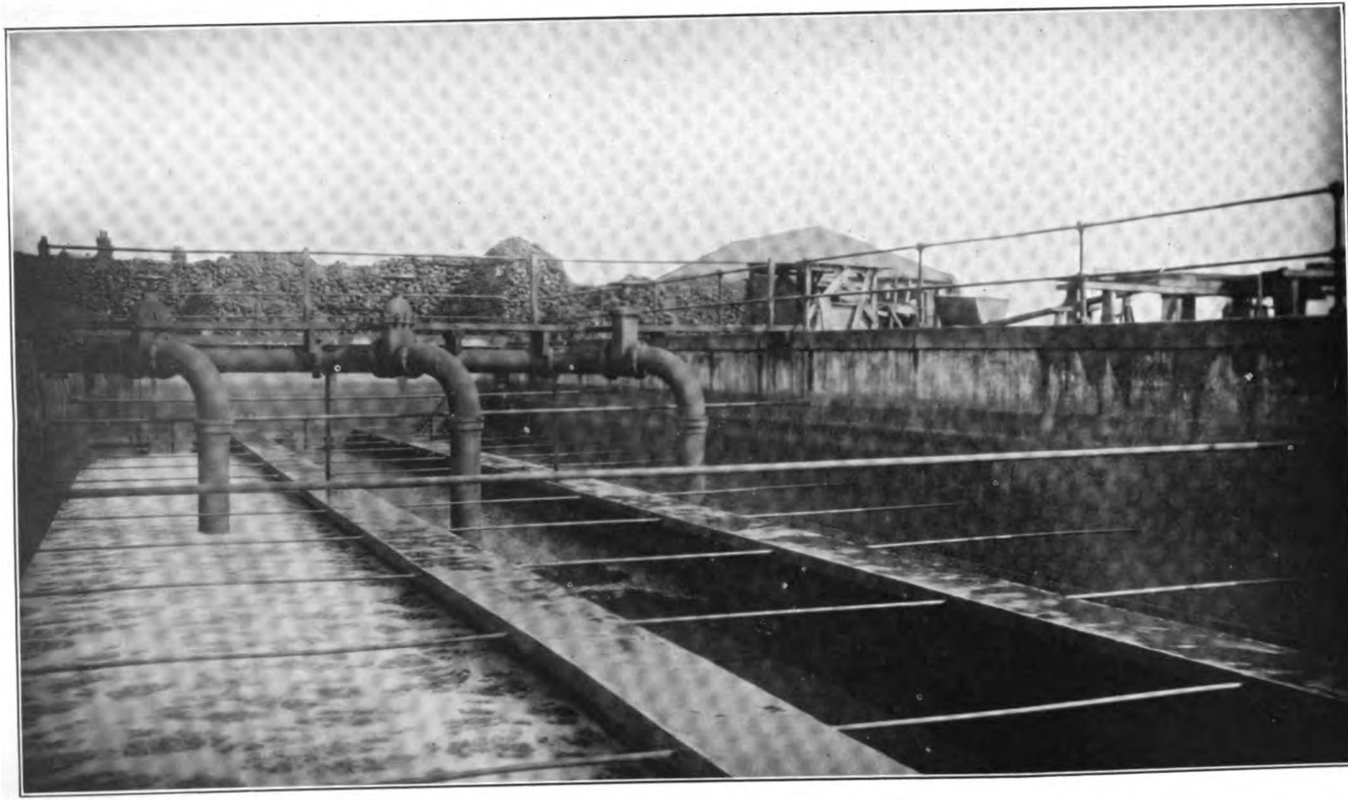
It would appear therefore that in Germany what is necessary at present is being done to prevent nuisance; though the scheme is not scientifically ideal, it is very practical.

That which is being done in England is very necessary, and greater refinement and extension of treatment to more towns is urgently needed if the streams are not to become plague spots.

Recovery of by-products is more in vogue in England than in Germany.

The collecting systems in Germany are laid down more systematically than in England.

The areas used in each country per million gallons are not comparable, but buildings and tankage, and especially sludge area, are less in Germany than in England.



Roughing Filter, Salford, England.

COMPARISONS OF AMERICAN CONDITIONS WITH GERMANY AND ENGLAND

Lacking the prejudices of the English and Germans, the American can assimilate the best from each, and it has been found in our own case that German tanks combined with English filters give excellent results. The absence of as much suspended matter in American sewages makes them more easily handled, and the sewage, on account of its dilution as compared to European sewage (being from 4 to 10 times more dilute), can be passed through bacterial filters at greater speed, but the effluent of our works compare unfavorably with those of European works in percentage of solids removed.

In tankage there has not been sufficient operation to compare results.

Results in the case of contact beds depend upon the composition of raw sewage. In America they give good results, but unless conditions are especially favorable, they will not be adopted on account of the relatively large area required.

In bacterial beds of sprinkling filter type good distribution has been obtained with fixed nozzles and spray, even in winter, as at Gloversville, N. Y., and in other places having a cold climate.

As to sludge disposal, plants have not been operated long enough to prove or disprove the efficiency of any method, but interest is aroused in the so-called sludge digestion tanks of Baltimore, Md.

Much interest is enlisted in the results to be obtained from the Emscher tank sludge and method of disposal, with dilute American sewages, of which Philadelphia has the first large tank.

A general review of American sewage disposal works, indicates that, having been constructed later than the existing English and German plants, they have avoided some

of the inefficient methods, and will be operated on advanced lines. They are therefore attracting the interest of both German and English engineers.

The sanitarians in America must work out their own problems, according to local conditions, profiting by the observation of those in the old world.

The treatment of the portion of storm water between 3 and 6 times the dry weather flow upon separate filters is not advisable in America, owing to the dilute sewages.

The methods of treatment rather than design of works are enlightening to the American engineer, excepting as to the design of recent extensions comprising bacterial filters.

GEORGE E. DATESMAN,
Principal Assistant Engineer.

July 3, 1913.

INDEX

PAGE

DISCUSSION OF POLICIES

THE PLAN RECOMMENDED FOR THE COLLECTION, TREATMENT AND DISPOSAL OF THE SEWAGE OF THE CITY OF PHILADELPHIA.

APPENDIX E.

REPORT OF THE PRINCIPAL ASSISTANT ENGINEER UPON AN EXAMINATION OF SYSTEMS OF SEWAGE DISPOSAL IN THE PRINCIPAL CITIES IN EUROPE, WITH DEDUCTIONS AND COMPARISONS, AFTER AN INSPECTION IN APRIL-JUNE, 1913.